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FENCO SHAWINIGAN ENGINEERING (1985) LIMITED

A DIVISION OF **Lavalin**

TECHNICAL/ECONOMIC STUDY OF THE FEASIBILITY OF SUPPLYING AND UTILIZING LINGAN / PHALEN MINE METHANE AT LINGAN GENERATING STATION

[Part of the Program of the Federal Panel on Energy R&D (PERD)]

FINAL REPORT

Volume 1 of 2

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Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada.

SSC File No.: 06SQ.2344-0-9033

Contract File No.: 23440-0-9033/01-SQ

153 pp

CANMET Scientific Authority: Dr. F.D.S. Preto

Date: March, 1991

MICROMEDIA

TECHNICAL/ECONOMIC STUDY OF THE FEASIBILITY OF SUPPLYING AND UTILIZING LINGAN / PHALEN MINE METHANE AT LINGAN GENERATING STATION

Revision History

Version #	Issue Date	Reason for Revision
1.0	91/01/29	DRAFT issue for Technical Steering Committee review.
	91/02/12	Addendum #1 issue to TSC
1.1	91/03/13	Updated following TSC review

ACKNOWLEDGEMENTS

This study was carried out by Fenco Shawinigan Engineering (1985) Limited, of Halifax, Nova Scotia on behalf of the Committee on Atlantic Coal. Funding for the study was provided jointly by Energy, Mines and Resources Canada, The Nova Scotia Department of Mines and Energy, Nova Scotia Power Corporation, Cape Breton Development Corporation, Environment Canada and the Canadian Electrical Association.

The study was managed by a Technical Steering Committee made up of members representing the following funding agencies: Energy, Mines and Resources Canada, The Nova Scotia Department of Mines and Energy, Nova Scotia Power Corporation and Cape Breton Development Corporation.

The study team wishes to express its appreciation and thanks to the members of the Technical Steering Committee for the valuable assistance and guidance received from them throughout the course of the study.

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EXECUTIVE SUMMARY

This document is the Final Report for a study undertaken by Fenco Shawinigan Engineering Limited (FSEL) and commissioned by the Committee on Atlantic Coal. The over-all objective of the study was to assess the technical and economic feasibility of supplying and utilizing Lingan and Phalen Mine Methane at Lingan Generating Station as combustion air, reburn fuel, or a combination of the two, thereby reducing the environmental impact of both greenhouse gas and acid gas emissions.

Mine Methane is the general term for either of two sources of methane-laden air discharged from the Lingan and Phalen coal mines, which are owned and operated by Cape Breton Development Corporation (CBDC). The first source of methane is in the ventilation air used to purge the mine workings of methane which escapes from the coal as it is being mined. This source, called Mine Return Air (MRA) typically has a methane concentration of about 0.4%. The second source of methane, called Mine Drainage Methane (MDM), comes from a system of methane gas collection from rock strata during mining operations. This has a methane concentration of about 50%.

The rationale for the study derives from the fact that the total methane contained in MRA and MDM combined has the equivalent greenhouse effect of CO_2 emitted from a 500 MW coal-fired power plant. This is currently an unused resource and it is desirable to extract the energy contained therein. Additional environmental benefits accrue from reducing the levels of sulphur dioxide (SO_2) and nitrogenous oxides (NO_X) emissions from the power plant, due to methane displacing some of the coal burned.

The methodology adopted was to define a number of ways in which MRA and/or MDM could be utilized, explore each of the options thus defined and pick the "best" option for further study. The "best" would be that option which maximized environmental benefits (and thus coal consumption reductions), maximized the utilization of methane, had minimal negative impacts on boiler performance and had acceptable financial characteristics in terms of net present value and payback. Conceptual designs for the selected option would then be developed and associated costs estimated for implementing the project.

Results of the initial review of Mine Methane utilization options and recommendations for further study were presented to the Committee on Atlantic Coal in the study Interim Report, issued August, 1990. The Interim Report recommended that MRA and MDM be blended at the Lingan coal mine site and the blended gas (essentially enriched MRA) be transported to Nova Scotia Power Corporation's (NSPC) Lingan Generating Station in a duct. At the power plant, the enriched MRA would be admitted to the boilers as secondary or combustion air. These recommendations were accepted by the Committee and the balance of the study focused on producing conceptual design details, cost estimates and boiler performance predictions.

The conceptual design proposes that a 4.0m diameter "feeder" duct be connected to the MRA discharge point at each mine site. The feeder ducts connect together close to the site of the Phalen mine MRA discharge point and the combined enriched MRA stream is then transported to Lingan Generating Station in a single 4.8m diameter transmission duct. MDM collected from Lingan Mine is currently discharged to atmosphere at the mine site. Some time soon it is expected that an MDM system will be installed at the Phalen Mine. This new system will be tied into the Lingan MDM system at the gas plant and MDM from both mines will be discharged at Lingan Mine. It is proposed to blend MDM into the MRA stream at Lingan Mine in a special duct blending section interposed in the feeder duct within the Lingan mine site.

The transmission duct will follow a route mainly north of the Lingan Beach Road, generally not visible from the road, except where the feeder duct from Lingan Mine crosses the road to meet up with the corresponding feeder duct from Phalen Mine. This route was found to be optimum in term of distance, number of road/rail crossings and construction costs. The feeder duct sections and transmission duct will be fabricated from helical corrugated steel pipe with an internal galvanized steel liner to reduce MRA flow friction losses. Externally applied insulation will reduce MRA heat loss, substantially eliminating condensation within the duct. All duct sections will be run above ground on elevated steel supports.

MRA flow in the transmission duct will be induced by a duct fan located close to the power plant. The transmission duct terminates close to the power plant at the fan suction end breeching. The final section of duct from the fan discharge breeching to the power plant is referred to as the delivery duct and will follow an elevated, inclined route to the top northeast corner of the boilerhouse. The duct then will run southward along the side of the boilerhouse where it will interconnect with each of the boiler Forced Draft (FD) fan intakes. Figure E-1 shows the general layout of the proposed MRA transport system.

Within the power plant, the key safety issue identified was that methane, even in low concentrations, may increase the propensity for fires and/or explosions in the coal mills. This issue has been addressed and the proposed boiler modifications are such that primary air (PA) used to transport pulverized coal from the coal mills into the boiler will be exposed to the least possible amount of MRA. This will be accomplished by adding separate PA fans and ducting to bring non-MRA boilerhouse air to the mills. The Ljungstrom air heaters will also be modified so that leakage from the secondary (MRA) to the primary air stream is minimised. In addition, the proposed interface between the MRA delivery duct and the FD fan intakes does not permit MRA to enter the boilerhouse space.

The overriding design goal with regard to system control was to ensure that the operational practices of both CBDC and NSPC are not affected by adding an MRA utilization system and that an emergency shut-down of this system has no operational impact on either the coal mines or power plant. This goal has been realized in the proposed design. Extensive control and instrumentation has been proposed to detect MRA leakage outside of the MRA duct system. In addition, the concentration of the MRA stream will be carefully monitored throughout, particularly at the MDM blending point, to ensure that potentially explosive methane/air mixtures will not be formed.

Environmental benefits are derived from the project in terms of reductions to SO_2 and NO_X emissions as a result of reductions in coal consumption. SO_2 emission reductions have been quantified, based on the amount of net coal savings, to be an average of 5,430 tonnes per year over the project life. NO_X emission reductions are less rigidly tied to coal savings; it has been suggested that reductions of the order of 5%, or approximately 600 tonnes per year, will be achieved. Most importantly, the proposed system design almost completely eliminates methane discharges to atmosphere and almost all of the available methane is utilized.

Project costs have been estimated to be $ 50.64 million (1990 dollars), broken down as follows:

Direct Costs:	33.32
Indirect Costs:	17.32

	50.64

The present value of net benefits that accrue from the project are predicted at $ 54.61 million, which implies a net present value of $ 3.97 million. Cash flows from the project indicate a discounted payback period of 18 years. The project is assumed to have a 20 year life, from an "in-service" date of January 01, 1993.

Using an NSPC supplied figure for the life-cycle costs of reducing SO_2 by installing limestone scrubbers, an additional "notional" benefit for SO_2 reductions of over $ 41 million can also be attributed to the project benefits. If this benefit were to be viewed with the direct project benefits, the corresponding NPV and payback figures would be $ 45.12 million and 9 years.

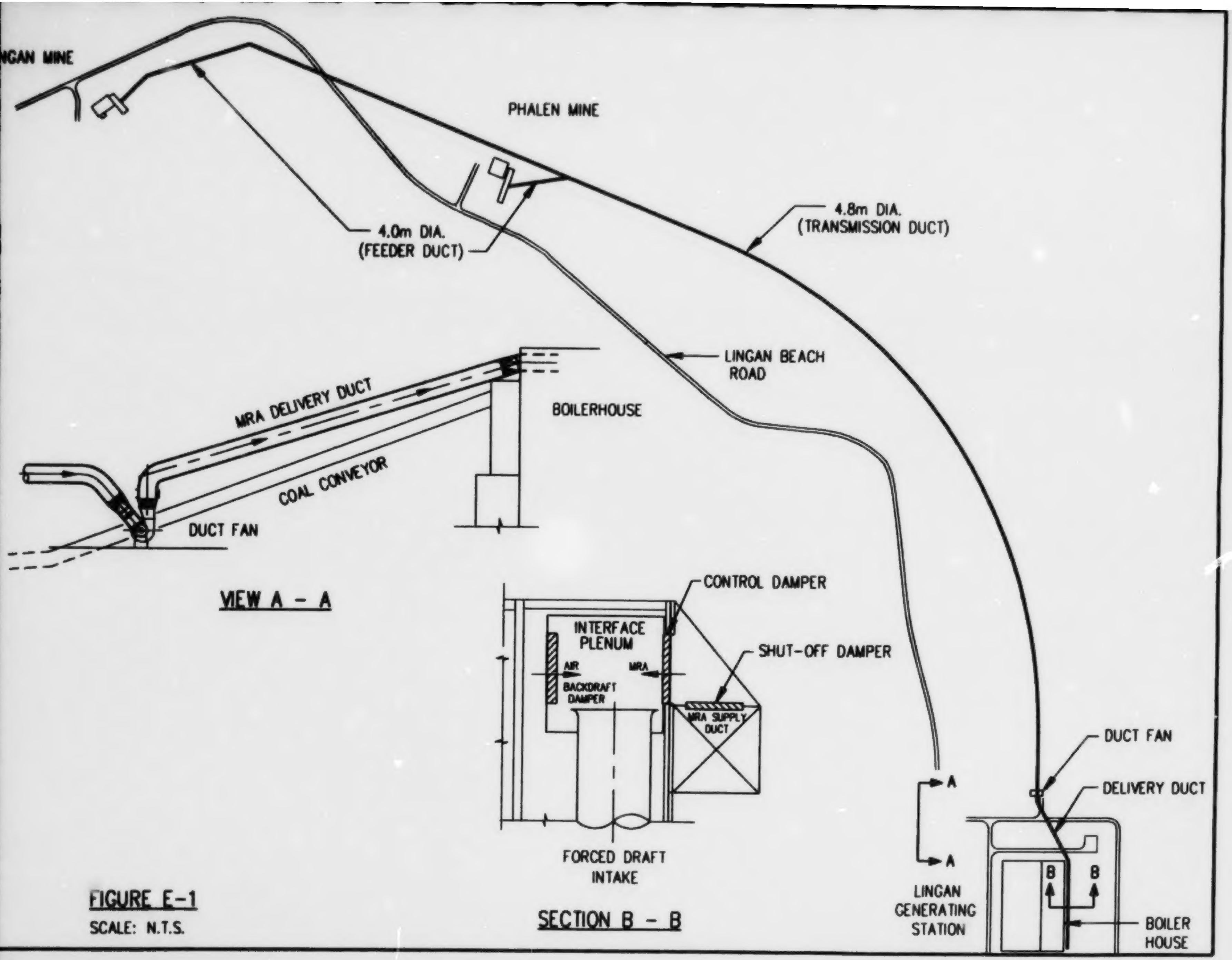


FIGURE E-1

SCALE: N.T.S.

TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

1.1 GENERAL 1-1
1.2 PROJECT BACKGROUND 1-2
1.3 OPTIONS STUDIED 1-3

1.3.1 Use of Mine Return Air 1-3
1.3.2 Use of Mine Drainage Methane 1-3
1.3.3 Use of Mine Return Air Plus Mine Drainage Methane . . 1-4

1.4 METHODOLOGY 1-5

2.0 CONCLUSIONS AND RECOMMENDATIONS 2-1

2.1 RECOMMENDED PROJECT 2-1
2.2 RATIONALE FOR SELECTED OPTION 2-2

3.0 BASIC DATA AND DEDUCTIONS 3-1

3.1 MINE RETURN AIR 3-1

3.1.1 MRA Quantities and Qualities 3-1
3.1.2 MRA Security and Longevity of Supply 3-3
3.1.3 MRA Long Term Flow Predictions 3-4

3.2 MINE DRAINAGE METHANE 3-4

3.2.1 MDM Quantities and Qualities 3-4
3.2.2 Security and Longevity of Supply 3-5
3.2.3 MDM Long Term Flow Predictions 3-5

3.3 POWER PLANT DATA 3-6

3.3.1 Plant Operations and MRA / MDM Utilization 3-8

3.4 MRA/MDM CONVEYING SYSTEM CAPACITY 3-10
3.5 MRA / MDM FLOWS AND METHANE CONCENTRATION CHANGES 3-11
3.6 GENERAL DESIGN PARAMETERS 3-13

3.6.1 System Operating Constraints 3-13
3.6.2 Physical 3-14
3.6.3 Financial/ Economic 3-14

4.0 TRANSMISSION DUCT 4-1

4.1 GENERAL 4-1

4.1.1 Site Description 4-1
4.1.2 Geotechnical Investigation 4-3
4.1.2 Design Criteria 4-5

4.2 ROUTE DESCRIPTION 4-7

4.2.1 General 4-7
4.2.2 South Route 4-8
4.2.3 Central Route 4-9
4.2.4 Lingan Beach Road Route 4-10
4.2.5 North Route 4-12
4.2.6 Route Selection 4-12

4.3 DUCT DESCRIPTION AND SUPPORTS 4-17

4.3.1 General 4-17
4.3.2 Concrete Duct 4-18
4.3.3 Fibreglass Reinforced Plastic Duct 4-20
4.3.4 Wood Stave Duct 4-21
4.3.5 Aluminum Duct 4-22
4.3.6 Steel 4-22

4.3.6.1 Welded Steel Pipe (WSP) 4-23
4.3.6.2 Corrugated Steel Pipe Duct (CSP) 4-24

4.3.7 Duct Foundations and Supports 4-28

4.4 CRITICAL DIMENSIONS 4-31

4.4.1 Transmission Duct 4-31
4.4.2 Duct Insulation 4-31

5.0 LINGAN MINE INTERFACE 5-1

5.1 DESIGN CRITERIA AND OPERATING CONSTRAINTS 5-1
5.2 MINE FAN & DUCT INTERCONNECTION 5-1
5.3 MDM BLENDING 5-3

6.0 PHALEN MINE INTERFACE 6-1

6.1 DESIGN CRITERIA 6-1
6.2 MINE FAN & DUCT INTERCONNECTION 6-1

7.0 GENERATING STATION INTERFACE 7-1

7.1 DESIGN CRITERIA 7-1
7.2 DUCT FAN SELECTION & LOCATION 7-1
7.3 DELIVERY DUCT DESIGN & ROUTING 7-4
7.4 INTERCONNECTION TO F.D. INTAKES 7-6
7.5 ELECTRICAL SUPPLIES TO MRA FAN AND P.A. FAN MOTORS 7-8

8.0 BOILER MODIFICATIONS AND PERFORMANCE PREDICTIONS .. 8-1

8.1 SEGREGATION OF THE PRIMARY & SECONDARY AIR STREAMS 8-2

8.1.1 Splitting the Air Side of the Existing Ljungstrom Air Heater 8-2
8.1.2 Separate Tubular Air Heater 8-3
8.1.3 Separate Steam Coil Heater 8-5

8.2 FLUE GAS / AIR PULVERIZED COAL DRYING AND CONVEYING SYSTEM 8-6
8.3 SELECTED BOILER MODIFICATION OPTION 8-8

8.3.1 Description of Air Heater Modification 8-9

8.4 BOILER PERFORMANCE PREDICTIONS 8-14

8.4.1 Reductions in Coal Consumption Due to Burning MRA 8-14
8.4.2 Fan Power Consumption Changes 8-19
8.4.3 MRA Fan Power 8-19
8.4.4 Reduced Coal and Ash Handling 8-20
8.4.5 Coal Consumed in Preheating MRA 8-20
8.4.6 Ventilation Heating Avoided 8-21

9.0 SYSTEM CONTROL PHILOSOPHY 9-1

9.1 SYSTEM OPERATING CONSTRAINTS 9-1
9.2 MRA DELIVERY - CONTROL REQUIREMENTS AND SAFETY ISSUES 9-1

9.2.1 System Safety and Protection 9-1

9.2.2 Fan Control Scheme 9-2
9.2.3 MRA Flow Metering 9-3

9.3 BOILER CONTROL MODIFICATIONS 9-4

9.3.1 Flow Control 9-4
9.3.2 Shutdown Control 9-4

10.0 LAND USE AND ENVIRONMENTAL CONTEXT 10-1

10.1 IMPACTS 10-1

10.1.1 Benefits or Positive Impacts 10-1
10.1.2 Costs or Negative Impacts 10-2

10.2 RELEVANT LEGISLATION 10-2

10.2.1 Federal Legislative Context 10-3

10.2.1.1 Environmental Assessment Review Process (EARP) 10-3
10.2.1.2 Canadian Environmental Protection Act (CEPA) 10-5
10.2.1.3 Other Federal Statutes 10-5

10.2.2 Provincial Legislative Context 10-6

10.2.2.1 Environmental Protection Act 10-7
10.2.2.2 Environmental Assessment Act 10-8
10.2.2.3 Pipeline Act 10-9
10.2.2.4 Dangerous Goods and Hazardous Wastes Management Act 10-10
10.2.2.5 Private Ways Act 10-10
10.2.2.6 Other Provincial Legislation 10-11

10.3 RELATED MATTERS 10-12

10.3.1 Rights of Way 10-12
10.3.2 Liability in Respect to Nuisance 10-13

10.4 ACTIONS ARISING FROM ENVIRONMENTAL LEGISLATION 10-14

10.4.1 Assessment 10-14
10.4.2 Approvals/Permits 10-15

10.5 CONCLUSIONS - MRA DUCT - LAND USE AND ENVIRONMENTAL ISSUES 10-16

11.0 PROJECT FINANCIAL ANALYSIS 11-1

11.1 BASIC ASSUMPTIONS 11-1
11.2 BASE CASE ANALYSIS 11-1

11.2.1 Methodology 11-1
11.2.2 Options Studied 11-2
11.2.3 Operating & Maintenance Costs 11-3
11.2.4 Cost Estimates - Use of MRA Combined with MDM ... 11-4
11.2.5 Present Value Analysis 11-5

11.3 SENSITIVITY ANALYSIS 11-5

Appendix 1 References

Appendix 2 Correspondence with Vendors & Sub-Consultants Reports

2.1 MRA Duct Fan

2.2 MRA Transmission Duct

2.3 Miscellaneous Vendor Correspondence

2.4 CANMET Report

2.5 Geotechnical Report

2.6 T.U.N.S. Report

2.7 Boiler Manufacturers Report & Correspondence

Appendix 3 Detailed Cost Estimates

Appendix 4 List of Drawings

Appendix 5 Interim Report

1.0 INTRODUCTION

1.1 GENERAL

This document is the Final Report for a study undertaken by Fenco Shawinigan Engineering Limited (FSEL) and commissioned by the Committee on Atlantic Coal. The over-all objective of the study was to assess the technical and economic feasibility of supplying and utilizing Lingan/Phalen Mine Methane at Lingan Generating Station as combustion air, reburn fuel, or a combination of the two, thereby reducing the environmental impact of both greenhouse gas and acid gas emissions.

The first source of methane is in the ventilation air which is used primarily to purge the mine workings of methane which escapes from the coal as it is being mined. A large suction fan draws air down through the mine and back to the surface where it is discharged to atmosphere as Mine Return Air (MRA). At this point it contains 0.4% - 0.6% methane. Both mines operate using this technique and their ventilation fans are within 2.8 km of Lingan power plant.

The second source of methane, called Mine Drainage Methane (MDM), comes from a system of suction pipework driven into the rock strata forming the roof above the coal seam. As the coal is removed and the roof collapses, methane collects in the strata from where it is withdrawn using suction pipes. The suction pipework leads to vacuum pumps at the mine surface works, and these discharge the methane at concentrations of about 50% methane and 50% air, to atmosphere.

There is potential financial benefit to be derived from conveying either the MRA, MDM or a mixture of the two from the two mines and using it as combustion air in the boilers at Lingan Generating Station.

1.2 PROJECT BACKGROUND

There is much in favour of exploring methods of utilizing methane expelled to atmosphere as a result of the Lingan/Phalen coal mining operations. Perhaps most important is that methane is a gas which contributes significantly to the "greenhouse" effect. In fact, it has been shown [Ref. 11 & 12] that methane contributes more to the greenhouse effect (approximately 30 times) than the equivalent volume of carbon dioxide (CO_2). However, the molecular equivalency of methane and carbon dioxide with respect to the greenhouse effect is an area requiring further clarification due to the many divergent views in the scientific literature. The volume of methane contained in the MRA alone expelled from the coal mining sites is equivalent to the carbon dioxide emitted from a thermal power plant of about 300 MW capacity operating continuously. The total methane contained in MRA and MDM combined has the CO_2 equivalent greenhouse effect of about 500 MW continuous thermal power plant operation. Therefore, methods to minimize the emission of methane into the atmosphere must be given serious consideration, considering the goal of limiting CO_2 emissions to approximately 1990 levels. It is also recognised that, for the same energy input, burning methane as opposed to coal reduces the amount of CO_2 generated by the burning process by almost half.

Additional benefits to the environment stem from a reduction in sulphur dioxide emissions at the power plant due to the methane displacing some of the coal which contains sulphur and also a reduction in nitrogenous oxides emissions, again as a result of displacing some of the coal.

A second driving force for this study derives from the potential financial benefits to be gained from burning methane. This study looks at the concept of bringing both MRA and MDM to the Lingan Generating Station and offsetting coal consumption with methane. This approach is perhaps the only feasible way of dealing with such a low percentage of methane in air, such as exists in MRA.

1.3 OPTIONS STUDIED

1.3.1 Use of Mine Return Air

An earlier 1983 study carried out by (FSEL) [Ref. 1] investigated transporting MRA from the mines to the power plant in a large duct which would be either buried, (partially or completely) or surface run.

The present study re-examined the options presented then using updated data on available MRA flows, as well as revised meteorological and geotechnical data. The objective was to select a single route for the duct from the preliminary options presented in the 1983 study and to work out the conceptual design details, such as, for example, locating the MRA duct fan and interfacing with Lingan Generating Station boilers.

It should be noted that due to the extremely low concentration of methane in MRA, increasing the methane concentration from 0.4 - 0.6% to some higher figure would be very expensive. Also, during this process, the methane concentration would have to pass through the explosive range, thus requiring suitable equipment and safeguards. For these reasons, this option was not explored in this study.

1.3.2 Use of Mine Drainage Methane

There are a number of ways in which MDM could be utilized. A previous study, also carried out by FSEL [Ref. 2], explored the concept of using MDM for power generation at the mine site. The present study focuses on MDM usage at Lingan Generating Station only, i.e. transporting the MDM from the mine egress point to the power plant.

Two specific options were studied, both looking at the potential for MDM to be used as a "reburn" fuel. Reburn in this context refers to a technique wherein an auxiliary fuel with less tendency to generate NO_X is introduced into the furnace at a suitable point adjacent to the main burner (coal) flame. The result is a significant reduction in the formation of NO_X. Using MDM in this manner has potential environmental benefits above and beyond those of using methane in MRA. As a reburn fuel MDM can have the effect of reducing nitrogenous oxide (NO_x) emissions to a greater extent than it would have if used as a displacement fuel only. A question to be resolved in this study is whether the improvement in NO_x emissions is worth the expense of compressing and delivering the gas to the power plant, plus modifying the boilers to accept the reburn fuel.

The first option considered was to simply compress the MDM to about 415 Kpa (60 psig) followed by drying. Compressors and dryers would be installed at the mine and a relatively small pipe (200 mm) used to convey the compressed gas to the power plant where it would be used as a reburn fuel. The second option consisted of separating the methane content of MDM from air such that the gas delivered to the power plant boilers would comprise close to 100% methane. A number of processes were examined to achieve this result and it was decided to further explore the most promising of these - pressure swing adsorption. Again, equipment for this would be installed at the mine with the resulting concentrated methane being delivered to the power plant.

1.3.3 Use of Mine Return Air Plus Mine Drainage Methane

At Lingan Mine, the MRA fan and the MDM extraction system are within a hundred metres of each other. A final option that was studied was to simply interconnect the MRA and MDM discharges in such a way as to enrich the methane content of MRA and transport this enriched gas to the power plant in a manner similar to using MRA alone.

The advantages of this option were felt to be significant in that both sources of methane could be used at essentially the same level of capital spending as implementing an MRA supply project alone. Also, the feeling was that benefits such as avoided coal costs and most emission figures obtainable with separate MRA and MDM projects could be obtained with the combined system. It was recognised at the outset that using MDM in this manner would forego some of the NO_x reduction that would be achievable, were MDM to be used as a reburn fuel.

1.4 METHODOLOGY

The methodology adopted for the study was to explore each of the options outlined above and, by applying criteria relating to environmental and financial costs/benefits, arrive at a single project that would be examined in more detail.

The first phase of the study was devoted to this exercise and concluded with an interim report (see Appendix 5). This showed that the implementation of an MRA system, in much the same way as was envisaged in the earlier 1983 study [Ref. 1], would be technically and financially viable, in addition to achieving reduced atmospheric emissions. The potential for using MDM as a reburn fuel was explored in this phase. CANMET Laboratories, Ottawa, were called upon to test the effects of using MDM in various concentrations of methane, in conjunction with a sample of a typical coal blend to be used at the Lingan Generating Station. The objective of these laboratory tests was to quantify the expected improvements in NO_x emissions. It was anticipated that utilizing MDM at about 50% methane concentration would reduce NO_x emissions to a lesser extent than the reduction achievable by using a more concentrated methane gas.

This parallel study concluded that the best use of MDM was to simply add it to the MRA stream and transport the now slightly enriched MRA to the power plant for use as combustion air. The only incremental benefit which would be realized by MDM combustion over and above those achievable by blending

MDM with MRA are the incremental NO_x reductions. Out of interest, the cost/benefit analysis of using MDM as a fuel proved to be attractive. However, almost all of the benefits can be achieved at a fraction of the cost by blending MRA with MDM at the mine.

NSPC indicated at a progress meeting July 1990, that these costs were not encouraging as other technologies could achieve a reduction in NO_X at less cost/tonne. Based on this, a decision was made that the balance of this study would focus on blending MDM with MRA and conveying the blend from both Lingan and Phalen mines for use as combustion air at Lingan Generating Station.

When a single project was thus defined, the second phase of the study focused on developing concept designs so that an estimate of capital and construction costs could be established. At this stage it was felt important to provide an integrated system which fully addresses the operational safety requirements of CBDC and NSPC, and can be seen to be technically sound.

The project was divided into five areas of design work:

- Area #1 - Duct design and routing analysis;
- Area #2 - Lingan Mine - MRA and MDM;
- Area #3 - Phalen Mine - MRA;
- Area #4 - Lingan Generating Station fan and delivery duct; and
- Area #5 - Modifications to Boiler and Auxiliaries.

The work completed on Area #1 included a rationale for selecting the chosen route, a review of alternative construction techniques and selection of an integrated design concept which caters to the constraints identified. These constraints include requirements and availability of space at CBDC and NSPC facilities as well the difficulties associated with erecting a major structure on undeveloped lands.

Areas #2 and #3 are similar, and the work here included the development of designs for interconnecting the mine ventilation fan discharge ducts with the MRA duct. These designs, particularly for blending MDM with MRA, called for careful consideration of safety (regulatory) issues.

Area #4 dealt with the routing of the duct onto the Lingan Generating Station site, locating the duct fan, delivery ductwork and its interface to the power plant as well as interaction of the duct system with power plant operations. The feature which was of concern to NSPC was to ensure that MRA did not escape into the boiler-room space under normal or upset conditions of plant operation.

Area #5 focused on the modifications to the boiler plant to accommodate the use of MRA. Discussions with NSPC personnel and information from studies of methane/coal mixtures [Ref. 9 & 10] established that using MRA for primary air (pulverized coal mill transport air) was considered more dangerous. Accordingly, the final design concept chosen has the primary air delivered by means of separate (new) primary air fans through ducts within the existing combustion air ductwork. Primary air tempering is achieved by modifying the existing Ljungstrom air heaters to a trisector configuration.

The study concluded with estimates of costs to implement the proposed concept design features. These estimates were based on assumptions about predicted plant utilization as well as MRA/MDM availability. The evaluation included a prediction of boiler performance and the benefits to the environment which will be achieved by the project.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 RECOMMENDED PROJECT

The study has shown that by adding MDM into the MRA duct and supplying the enriched MRA to the boilers at Lingan Generating Station, the environmental and financial benefits are maximized, in accordance with the stated objectives of the study. Briefly, these were to reduce the environmental impact of both greenhouse gas and acid gas emissions as well as to maximize the utilization of what is currently an unused and wasted resource. The pertinent figures for each of the benefits are shown in the accompanying Table 2.1 and are presented with corresponding figures for each of the design alternatives studied.

The benefits realized by the project are based on various assumptions about the economic life of the project, MRA and MDM availability and quantities, plant capacity factors over the project economic life, unit costs for coal and electrical energy displaced as well as the "value" to the project proponents of displacing both SO_2 and NO_X. These assumptions are listed in section 3.6.

The study also examined the relevant federal, provincial and local regulations and identified no significant regulatory impediment to the proposed project. There are legislative requirements for review of the project which can be readily met and should lead to the granting of permits. Although no regulations specifically focus on the aesthetic or visual impact of the project, this issue was addressed. To the extent possible therefore, the routing of the transmission duct has been largely out of sight from the public highway. Given that the site is an industrialized area and is predominantly owned by the project proponents, it was felt that, for the purposes of this study, the above ground structure would be an acceptable addition to the area.

2.2 RATIONALE FOR SELECTED OPTION

From a financial perspective, all of the options studied show a positive net present value using Client supplied criteria for escalation and interest rates. In fact, as can be seen from Table 2.1, the project with the most attractive financial features is that where MDM alone is compressed and transported to the power plant. However, it must be remembered that the chief objective of the study was to assess the technical/ economic feasibility of utilizing Mine Methane, with a view to reducing the environmental impact of both greenhouse gas and acid gas emissions. It was also regarded as important to maximize methane utilization as this valuable resource is essentially being wasted at present.

Implementing the MDM compression / delivery project alone will realize less than half of the environmental benefits obtainable by implementing the MRA/MDM blend option. This option also utilizes less than half of the available methane. On the other hand, implementing the MRA/MDM blend option maximises the reduction of greenhouse gas emissions, maximises the reduction in SO_2 emissions and achieves a substantial proportion of the NO_x emission reductions that can be obtained from methane substitution in a coal fired boiler. In addition, nearly all of the methane emitted from the mines is utilized.

In Table 2.1, the summary figures for each of three separate MRA and MDM utilization options studied are presented: MDM compression, MDM beneficiation and MRA/MDM blending. The data for the MDM projects were originally derived at the Interim Report and have not been revisited except as noted below.

Table 2.1 - Comparative Costs, Benefits and Emission Reductions

		MDM Compression (a)	MDM Beneficiation (b)	MRA & MDM Blend (c)
LIFE CYCLE COSTS	Direct ($m)	2.60	3.60	33.32
	Indirect ($m)	1.43	2.00	17.32
	O / M ($m)	3.12	5.41	incl.
	Total Costs ($m)	7.15	11.01	50.64
LIFE CYCLE BENEFITS	Net Coal /Energy Saved ($m)	29.51	26.56	54.61
	Average Net SO_2 saved (t/yr)	1,920	1,728	5,144
	Notional Value of SO_2 savings ($m)	15.36	13.82	41.15
	Net NO_x reduced (t/yr)	450	540	600
LIFE CYCLE NPV ($m)	excl. SO_2 notional value	22.36	15.55	3.97
	incl. SO_2 notional value	37.72	29.37	45.12
Discounted Payback Period (yrs.)	excl. SO_2 notional value	?	?	18
	incl. SO_2 notional value	?	?	9

Notes:

- All dollar figures are $CDN, December 1990
- In-service life: 20 years
- Cost of money: 10.25% per annum
- Inflation: 5% per annum
- cost of coal: $ 2.70 / 1050 MJ (1 Mbtu)
- cost of energy: $ 0.053 / kWh
- sulphur content: 3%

- figures from columns (a) and (b) are extracted from the project Interim Report, except where:
  - SO_2 reduction figures have been increased to take into account the higher sulphur content of the coal of record for the study. The Interim Report assumed a sulphur content of 2%.
  - MDM beneficiation benefits and SO_2 reductions have been reduced by 10% to account for methane losses in the beneficiation process.

In addition to the explicit financial benefits that accrue from net coal and energy savings, there are also notional values which can be attributed to the project. An alternative means of reducing SO_2 emissions consists of installing limestone scrubbers. NSPC has stated that the life-cycle costs of this alternative can at least be valued at $400/tonne [Ref. 4]. Therefore, by reducing emissions by about 5,144 tonnes per year, the SO_2 reduction benefit can be valued at over $ 41 million over the project life.

NO_X reductions attributable to the project are less easily defined as it depends on the actual performance of the installed burners. CANMET data indicates that there will be a reduction of 5% NO_X when using MRA as combustion air. 12,000 tonnes per year of NO_X are emitted when the plant runs at 80% capacity factor. Thus, the postulated reduction is 5% of 12,000 tonnes or 600 tonnes per year. This figure may vary according to the actual capacity factor of the plant.

It must be stated that these conclusions are derived from data for a system design which has been optimized to a preliminary level. Opportunities for improvements to the design probably exist in the areas of: duct construction systems, fan selection (fixed versus variable speed; axial versus centrifugal type fans), air heaters and interconnection between the duct fan and the boiler-plant. At the detail design stage, these areas should be re-evaluated together with a re-assessment of such basic information as MRA/MDM flows, methane concentration and predictions of flow.

Re-evaluating MRA and MDM flows, particularly with regard to the predicted life of Lingan Mine, could lead to different conclusions for duct sizing. A number of variables interact to arrive at an optimal system design. These include MRA/MDM flows and methane concentration; Duct construction system; Duct pressure drops at the suction and delivery side of the fan; Fan design, efficiency; Flow control system; Air heater modification and separation of primary and secondary air and finally the Generating Station capacity factor prediction.

3.0 BASIC DATA AND DEDUCTIONS

3.1 MINE RETURN AIR

3.1.1 MRA Quantities and Qualities

Cape Breton Development Corporation (CBDC) agreed to provide information to the study team. The following text is based on a CBDC letter, April 25, 1990, to the Study Technical Steering Committee [Ref. 3]. The word "methane," as used in this letter means a mixture of aliphatic hydrocarbons made up of 95% methane and diminishing amounts of higher molecular weight gases. Figure 3.1 and 3.2 are records of the methane content of MRA in April 1987 as measured at Lingan Mine.

Lingan Mine, over the next two years, plans to convert to a retreat mining system, with somewhat reduced total coal output compared to present rates. It has an MDM system which will continue to operate and is described in more detail in Section 3.2 of this report. Ventilation air flow (MRA) is expected to be maintained at current levels of 165 m^3/s. Methane content is forecast to remain roughly constant at 0.4%.

Phalen Mine ventilation air flow (MRA) is currently at 170 m^3/s and is expected to remain at this magnitude for the near future. Air flow rates and patterns are being changed to suit underground conditions. However, as the mined out area expands, it is expected that MRA flows will slowly increase. (Installed fan ventilation capacity is in excess of 300 m^3/s). Current methane content is 0.6% and is expected to remain at this concentration until the installation of a methane drainage system. Even with very high cutting rates on the retreat walls there appears to be no immediate need for an MDM drainage system, but for the purpose of this study it is assumed that it will be in place and that the quality of the MRA will be 0.4% methane. Preliminary

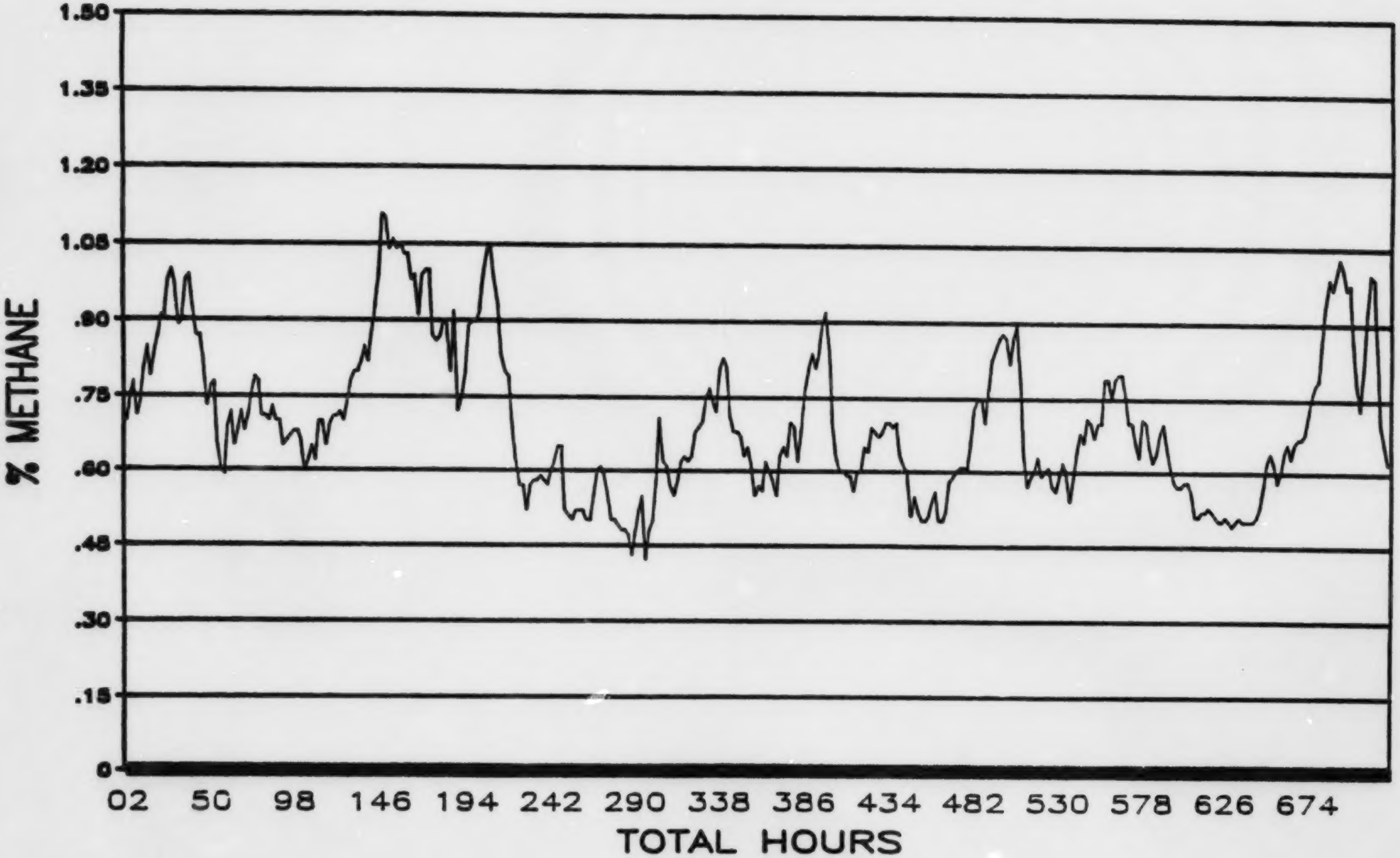


FIGURE 3.1 METHANE CONTENT OF MINE RETURN AIR

LINGAN COLLIERY

APRIL 1987

(TWO HOUR INTERVALS)

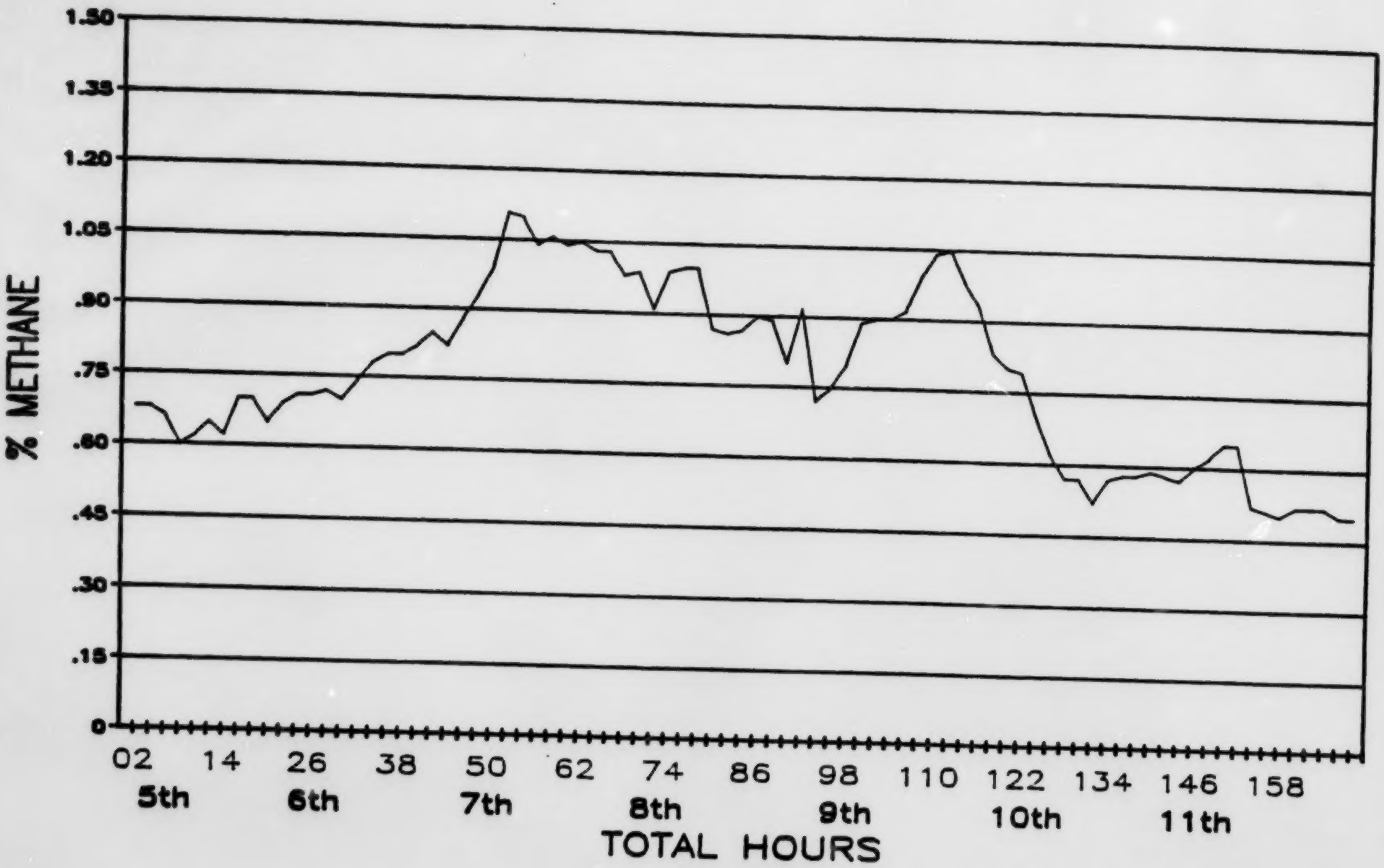


FIGURE 3.2 METHANE CONTENT OF MINE RETURN AIR

LINGAN COLLIERY

APRIL 5th to 11th, 1987
(TWO HOUR INTERVALS)

engineering for the Phalen MDM system was underway at the time of writing this report.

Levels of Lingan Mine MRA temperature and humidity were recorded in February, 1983, from a series of readings which were observed over a period of three weeks. It is surmised that in winter, the outside ambient temperatures and humidities are such that, after passing through the mine, the return air is less than saturated and at temperatures approaching 10°C (50°F).

Figure 3.3 - PSYCHROMETRIC CHART: AMBIENT AIR/MINE RETURN AIR is a prediction of annual conditions based on the readings taken in February/March, 1983, and records of climate at Sydney Airport. Two lines plotted on the chart show the expected range of conditions of the MRA immediately before and after the mine fan. It should be noted that the heating effect of these fans is beneficial towards reducing condensation in the duct. The insulation levels called for in the duct design will be sufficient to minimize condensation under all of the conditions plotted. However, at the planned air velocities in the duct, any condensation that may occur will have minimal consequences. From the above reasoning, the average annual condition of MRA before the mine fan (Point #9 on the chart) is 12.8°C (55°F) and 98% relative humidity. The calculation of MRA conditions arriving at Lingan Generating Station are based on these figures. The quantities are as follows:

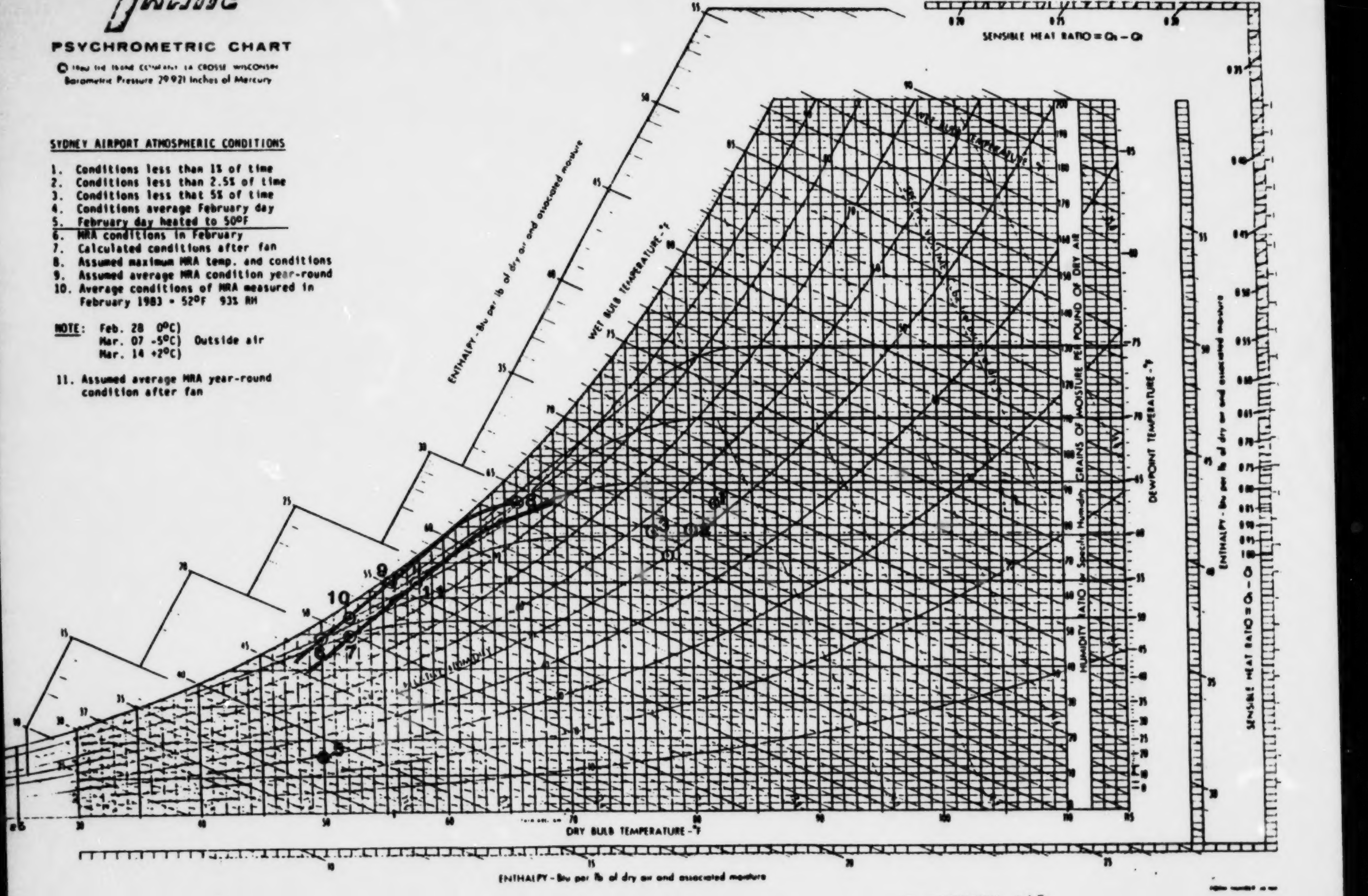
Table 3.1 - MRA make-up at 0.4% Methane

	LINGAN MINE	PHALEN MINE	
		Current	Maximum
Dry Air m^3/s	161.85	166.75	294.27
Moisture m^3/s	2.48	2.56	4.53
Methane m^3/s	0.67	0.69	1.20
Total	165.00	170.00	300.00

TRANE

PSYCHROMETRIC CHART

© [illegible] THE TRANE COMPANY LA CROSSE WISCONSIN
Barometric Pressure 29.921 Inches of Mercury



SYDNEY AIRPORT ATMOSPHERIC CONDITIONS

1. Conditions less than 1% of time
2. Conditions less than 2.5% of time
3. Conditions less that 5% of time
4. Conditions average February day
5. February day heated to 50°F
6. MRA conditions in February
7. Calculated conditions after fan
8. Assumed maximum MRA temp. and conditions
9. Assumed average MRA condition year-round
10. Average conditions of MRA measured in February 1983 - 52°F 93% RH

NOTE: Feb. 28 0°C)
Mar. 07 -5°C) Outside air
Mar. 14 +2°C)

11. Assumed average MRA year-round condition after fan

Spot checks on the MRA temperature throughout the year, from the two mines, are indicative of what may be found when continuous data are obtained. Table 3.2 below contains the available data:

Table 3.2 - MRA spot temperature readings

Month (1989/'90)	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Lingan °C	18	18	_	18	14	17	16	17	16
Phalen °C	14	14	12	10	10	10	10	11	11

Note: Lingan MRA is warmer due to:

- deeper mining;
- longer ventilation paths;
- more underground motors and equipment.

3.1.2 MRA Security and Longevity of Supply

Coal reserves at both Lingan and Phalen collieries are sufficient for many decades of mining activity at present rates of extraction. Limiting conditions are more imposed by distances from the mine entrance as workings move farther seaward. Other limits may be imposed by strata pressure as the depth of mining increases. However these factors are not expected to limit production over the next ten years.

The Federal Minister responsible for CBDC (Tom Hockin) has publicly restated (May 1990) that Lingan Mine must meet production targets in order to ensure continued government funding. The targets were not being met at that time, so there is serious concern that the mine could be closed. Notwithstanding this possibility, present mining plans are such that methane flows as outlined above will be sustained for at least 10 years as stated in the CBDC letter.

3.1.3 MRA Long Term Flow Predictions

For the purpose of this study it is assumed that Lingan Mine will continue operating for the 20 year life of the project and that the flows defined above will be achieved for that length of time. It should be noted that even if the Lingan Mine were shut down, it would be possible to continue ventilating the workings, albeit with some operating costs. A certain amount of pumping would be required to prevent the mine from flooding. Thus the methane which will continue to migrate from the strata into the mine workings can be flushed through by the air stream. Predictions of the decay rates for quantities of methane are not available for the Lingan Mine.

The long term prediction for Phalen Mine is for an upward trend in the quantity of ventilation air. Actual predictions are not available but the degree of oversizing of the fan capacity suggests that it will be significant.

3.2 MINE DRAINAGE METHANE

3.2.1 MDM Quantities and Qualities

Currently, contained methane flow from the gas extraction plant (MDM) is in the range of 0.5 to 0.6 m^3/s originating from the drainage system plus 0.15 m^3/s from the sealed long walls. At this time CBDC recommends a long term supply from the Lingan Mine gas extraction system be allowed for at 0.5 m^3/s of contained methane. This methane is diluted with entrained air so that the total gas mixture flow is therefore between 0.9 and 1.0 m^3/s. Similar flows and qualities are assumed for the future Phalen Mine MDM system.

The methane content of the MDM is now about 50%. With more attention to control of flow and quality from individual drainage holes this can easily be raised to 55% and with some additional expenditure in time and equipment a level of 60% is attainable. To improve quality substantially beyond 60%, if possible at all, would be very costly. The quality of the gas is expected to be easier to maintain as conversion to retreat mining is completed.

3.2.2 Security and Longevity of Supply

The security and longevity of supply for MDM is similar to the conditions outlined for MRA in Section 3.1.2. However, in the event that the Lingan Mine were shut down, there would be no point in maintaining MDM abstraction other than to attempt to sustain quantities for as long as possible. With no further system development underground, the resource will deplete within a matter of a few years.

It is planned that the proposed Phalen Mine MDM abstraction system will interconnect with the Lingan Mine system. Thus its MDM will be available from Lingan MDM extraction plant facilities. In the worst case (i.e. Lingan Mines shutting down), total MDM quantities would diminish to the level obtainable from Phalen only, or 1.0 m^3/sec.

3.2.3 MDM Long Term Flow Predictions

Total MDM flows from both Lingan and Phalen Mines, combined at the Lingan extraction facilities, will be 2.0 m^3/sec. Disregarding the possibility of Lingan Mine shutting down , this study assumes that this flow will last for at least 20 years.

3.3 POWER PLANT DATA

Lingan Generating Station comprises four almost identical units. During the preparation of the 1983 study report [Ref. 1], Nova Scotia Power Corporation (NSPC) kindly made available the boiler performance data which the boiler manufacturer had submitted with his equipment supply tender. The figures below are extracted from those data sheets. It should be noted that the maximum load figures for the boiler correlate with almost 167 MW. However, the actual turbines installed are rated at 158.2 MW. Other NSPC data sheets made available to the study team show that this corresponds to a steam flow rate of 1,023 Mlb/hr. The difference has been taken into account when calculating plant performance when methane is included in the combustion air.

Boiler Performance at Maximum Load

Steam Leaving Superheater	kg/h	490.3×10^6
Steam Leaving Reheater	kg/h	434.9×10^6
Excess Air Leaving Economizer	%	18
Quantity of Fuel	kg/h	56.98×10^6
Flue Gas	kg/h	731.4×10^6
Air	kg/h	627.88×10^6
Continuous Blowdown	kg/h	2.45×10^6

Pressure:	Steam Leaving Superheater	kPa(g)	12,770
	Steam Entering Reheater	kPa(g)	3,579
	Steam Leaving Reheater	kPa(g)	3,441

Temp.:	Steam Leaving Superheater	°C	541
	Steam Entering Reheater	°C	368
	Steam Leaving Reheater	°C	541
	Gas Leaving Economizer	°C	372
	Gas Leaving Air Heater	°C	173/161

	Water Entering Economizer	°C	244
	Water Leaving Economizer	°C	282
	Air Entering Heater	°C	27
	Air Leaving Heater	°C	284
Heat Losses:	Dry Gas	%	5.87
	H_2 and H_2O in Fuel	%	4.57
	Moisture in Air	%	0.14
	Unburned Combustible	%	0.20
	Radiation	%	0.20
	Unaccounted for	%	1.50
	Boiler Efficiency	%	87.52

Fuel as Fired:

Coal as defined in the contract specifications.

Proximate Analysis % by Weight	
Moisture	7.5
Volatile Matter	31.4
Fixed Carbon	50.0
Ash	11.1
Total	100.0

Ultimate Analysis % by Weight*	
Sulphur	4.0 (max.)
Btu/lb	12,000

* Only one component was identified.

3.3.1 Plant Operations and MRA / MDM Utilization

Extrapolations from the 1983 study [Ref. 1] indicate that the total current flow of 335 m^3/s supply of MRA would satisfy the combustion air (primary and secondary air) requirements for 392 MW of power generation. The primary air requirements are expected to be met by means of a separate supply system which is capable of up to 20% of the total combustion air at full load. For the purpose of this study it is assumed that at full load, the primary air will be 18% of the boiler load. Therefore, in order to use 335 m^3/s of MRA, the plant will have to be loaded to 478 MW. This can be shown as follows:

> Boiler requires 627.5 tonnes /hr of air @ 167 MW and generates 490 tonnes/hr of steam;
> Turbine is rated at 158 MW and requires 464.2 tonnes/hr of steam. Thus air requirements are
>
> 464.2 / 490 x 627.5 = 594.4 tonnes/hr
>
> Given that the air density at 15 Deg.C is 1.2254 kg/m^3, air volume required for 158 MW is 135 m^3/s.
>
> Now, 18% of air requirement is met from Primary Air. Thus, secondary air requirements (MRA) are 135 x .82 = 110.8 m^3/s.
>
> Thus, if 335 m^3/s were available to the boiler, the plant output required to utilize all of the MRA would be 335/110.8 x 158 = 478 MW.

The maximum amount of MRA which could be used is when the plant is at full capacity, i.e. at 632 MW. Allowing 18% for primary air which equates to 114 MW, the balance of 518 MW could be serviced by MRA. This would require a flow of about 442.6 m^3/s. This quantity may become available when Phalen is further developed and Lingan is at full production. However, in order to install ducts and fans for the higher flow, greater capital costs would be incurred. It is necessary, therefore to estimate the percent of time that high flows would be required.

Information on Lingan Generating Station future production was provided verbally by NSPC. The table below shows the forecast plant annual capacity factors for the next twenty years. From this, the annual amounts of MRA in excess of plant requirements can be calculated. These amounts are based on 335 m^3/s for present MRA availability and 442.6 m^3/s, which is the maximum acceptable flow.

Table 3.3 - Annual Plant Capacity Factors

YEAR	ANNUAL CAPACITY FACTOR (%)	% MRA IN EXCESS OF ANNUAL REQUIREMENTS	
		SUPPLIED AT 335 m^3/s	SUPPLIED AT 442.6 m^3/s
1990 - 2000	80	8	20
2001 - 2005	75	10	25
2006- 2013	65	19	35

3.4 MRA/MDM CONVEYING SYSTEM CAPACITY

To define the system capacity, the following factors must be taken into account:

- MRA availability is predicted to rise at an undefined rate.
- Lingan Generating Station capacity factors are predicted by NSPC to be generally decreasing, although at an uncertain rate.

Therefore, selecting the system capacity that must be reasonable over the life of the project involves a certain degree of judgement as a single figure cannot be predicted from available uncertain data.

The MRA utilization predictions presented above show that the supply rate of 335 m^3/s of MRA fits well with predicted plant utilization. The transmission duct dimensions were therefore optimized based on this flow. However, the duct fan itself can be designed with extra capacity. This will permit increases in flows to be achieved for short term demands, albeit at the expense of increased fan power.

In a normal system, fan power required by the system is proportional to the cube of the quantity for small variations in flow. Thus there is a penalty associated with oversizing the duct fan. The extra capacity would call for increased capital costs in terms of everything associated with the fan - motors, switchgear and cables. It may also call for increased supply transformer capacity. With this in mind, a figure for ultimate system capacity was fixed at 380 m^3/s, with no formal basis for its selection.

3.5 MRA / MDM FLOWS AND METHANE CONCENTRATION CHANGES

The proposed transmission duct system has been set up such that reducing combustion air demand from the power plant will result in MRA flow from Phalen Mine being reduced first, while keeping Lingan Mine MRA flow fully open. This is so as to enable MDM blending, carried out at Lingan, to be done with the maximum flow rate possible. The consequence of this is that the concentration of methane in the duct total air flow varies depending on plant load.

Thus, for a total MRA/MDM flow of 380 m^3/s, the sources of MRA and MDM will be as follows:

Table 3.5 - Methane Concentration in Duct at Full Capacity

SOURCE	FLOW m^3/s	% METHANE	m^3/s METHANE
Lingan MRA	165.0	0.40	0.660
Phalen MRA[1]	213.0	0.40	0.852
Total MDM	2.0	50.00	1.000
TOTAL	380.0	0.66	2.512

When Lingan Generating Station requires less than 380 m^3/s from the methane recovery system, MRA flow from Phalen Mine will be deliberately reduced and vented, resulting in an increased methane content when viewed as a percentage of the reduced total flow. As an example, if two of the four Lingan boilers were out of service, the remaining 300 MW would call for approximately 216 m^3/s of total MRA/MDM flow - 165 m^3/s from Lingan MRA, 2 m^3/s of MDM and the remaining 49 m^3/s from Phalen MRA. The resulting 216 m^3/s would have a methane concentration of 0.86%. This variation in methane concentration is of course central to the calculation of boiler performance predictions and project benefits, in terms of reduced coal consumption.

---

[1] This is greater than present (March 1991) flows.

3.6 GENERAL DESIGN PARAMETERS

The following section is a summary of all pertinent system operating constraints, design parameters and critical assumptions used during the project; it has been collected, in part, from data presented above.

3.6.1 System Operating Constraints

CBDC Requirements

1. In the event of a mine emergency, it must be possible to reverse the flow in the mine ventilation systems (ie. at Lingan and/or Phalen Mine).
2. The existing MRA exhaust flow rates must be maintained under CBDC control.
3. The Lingan MRA fan must be operationally independent of the system, as must be the Phalen fan. Thus if either MRA fan is shut down, the system controls must compensate to reduce flow to the Lingan Generating Station.

NSPC Requirements

1. Methane concentration must be monitored with safeguards built into the system to prevent any possible explosive mixtures arriving at the power plant.
2. Boiler operation must be able to revert to normal combustion air utilization without interrupting power generation.
3. Quantities of MRA delivered must be controlled to match boiler requirements.

3.6.2 Physical

	Lingan Mine	Phalen Mine
MRA Seasonal Temperature Range (Deg. C)	18 - 14	14 - 10
MRA Mean Temp. / ± Std. Deviation (Deg. C)	16.8 ± 1.4	11.3 ± 1.7
MRA Mean Rel. Humidity (%)	98	98
Current MRA flows at 0.4% methane (m^3/s)	165.0	170.0
Max. future MRA flows (m^3/s)	165.0	300.0
Current MDM flows at 50% methane (m^3/s)	1.0	0.0
Max. future MDM flows (m^3/s)	1.0	1.0
Condensate pH	neutral	
Particulate (%)	very low	

3.6.3 Financial/ Economic

Weighted Average Cost of Capital (%):	10.25
Inflation Rate (%):	5.00
Present Value discounting done to end of:	90/12/31
Project in-Service Date:	93/01/01
Project in-Service life (years):	20

Lingan Generating Station Capacity Factors:

1993 - 2000:	80%
2001 - 2005:	75%
2006 - 2013:	65%
Avoided cost of coal - ($/1050 MJ (1 MBtu)):	2.70
Cost of electrical energy ($/kWh):	0.056 [Ref. 7]
Notional value for the life-cycle cost of reducing SO_2 emissions ($/tonne):	400

4.0 TRANSMISSION DUCT

4.1 GENERAL

4.1.1 Site Description

The site of the proposed works comprises a land area of approximately 356 ha. As shown on drawing 58613-C-01 KEY PLAN; it is included within Cape Breton County and partly incorporates land within the Town of New Waterford. The site is represented graphically on drawing 58613-C-02 EXISTING CONDITIONS, which was prepared specifically for this project from previously unavailable source information. Prominent features on the site include CBDC's Lingan and Lingan Phalen Mines to the northwest, as well as NSPC Lingan Generating Station to the southeast. The site is bounded on the north by the Atlantic Ocean (Cabot Strait), and on the south by NSPC's high voltage electric transmission right-of-way. The central portion of the site is occupied by NSPC's ash lagoon, and disposal dump.

The Lingan Beach Road traverses the site predominantly in a northwest-southeast alignment, with the segment adjacent to Lingan Mine aligned due east-west, and the segment adjacent to Lingan G.S. aligned due north-south. CBDC's railway runs adjacent to the road at the Phalen Mine, then adjacent to the ash lagoon north dyke, from whence it follows a path parallel to the south side of Lingan Beach Road, crossing it near the north boundary of the NSPC property line.

The most recent government mapping of the site was prepared in 1973 based upon aerial photography recorded in 1972. At that time the Lingan Generating Station and Phalen Mine were non-existent so that the area of the present ash lagoon and ash dump were not yet developed. The Lingan Mine was in early stages of construction.

In order to complete this study mandate, the firm of Atlantic Air Survey was engaged by the Committee on Atlantic Coal to compile up-to-date topographic and planimetric cartography. 1:10,000 scale vertical black and white aerial photography was provided by CBDC, based on surveys flown on November 29, 1987 by Atlantic Air Survey. The 1:2000 scale mapping provided to the study team was edited, and drawn at 1:3000 scale to form the basis of our existing conditions drawing. Relevant information collected for this study was compiled on the drawings associated with the study.

During on-site visual inspections, few significant changes were noted from the conditions recorded in 1987. The most notable however, was the construction of a steel fish processing building in the vicinity of 5123700 N, 4612500 E (NB. Land Registration and Information Service (LRIS) Coordinate System). This structure was only partially constructed and was in an abandoned state throughout the study period. Anecdotal commentary from local residents, indicates the structure was constructed on behalf of an independent company with Federal Government; Atlantic Canada Opportunities Agency (ACOA) funding assistance. Furthermore it was intended to support aquaculture operations at the nearby Lingan Generating Station facility. Materials were observed being removed from the structure during the study period and it is uncertain whether the building will be completed or that operations will ever commence.

Also observed during site visits was the demolition of portions of the Lingan Mine coal handling structures including overhead conveyor galleries, storage silo, transfer house and associated foundations and supports. Such planimetric detail provided by the cartographer, but which is known to be out-of-date, was "screened" on our drawings to emphasize the information. Information known to exist but not indicated by the cartographer was not shown, however an appropriate note was included on the drawings to alert the reader. Additionally, information was drawn from previous Land Registry and Information Service (LRIS) charts and reproduced with "screened" lines to indicate that the structures are no longer apparent or are currently in ruins.

Specifically this refers to a number of gun emplacements (i.e. concrete bunkers) and observation buildings of World War II vintage, located near the Lingan Mine and adjacent the Lingan Beach Road. Not only do the foundations of these structures represent potential obstructions to duct supports but the probability of shallow tunnels between installations and in the vicinity is considered high. A cautionary note was therefore attached to our drawings.

Where possible, our drawing indexed relevant structures within the CBDC and NSPC facilities. Due to the resolution possible from the available aerial photography, not all structures and potential obstructions were indicated on the cartography produced. Our drawing however indicates a note where possible to alert attention to existing facilities not shown otherwise. Locations so noted were recorded by means of unmeasured visual observations only, and should not therefore be construed as precision measured sitings.

4.1.2 Geotechnical Investigation

The full geotechnical report prepared by sub-consultants is attached in Appendix 2. The following is a summary and overview of that report and other pertinent geotechnical information.

Geotechnical conditions across the site were represented by sample sites indicated on our drawings. These sample sites include: deep and shallow boreholes; test pits; standard penetration test probes; auger probes as well as hydrogeologic observation wells. The sample sites indicated were originally selected to determine subsurface conditions for the phased design/construction of four units at the Lingan Generating Station including both the ash disposal dump and ash lagoon. Additionally, many geotechnical sample sites were investigated for the many surface buildings for the Lingan and Phalen Mines.

The subsoil conditions over much of this site including the north east and west sections was described predominantly as loose to very dense, gravelly, sandy silt and/or gravelly silty sand, glacial till derived largely from local bedrock. Particles of quartzite and granite were commonly found dispersed throughout the till consistent with glaciation processes. Small sandstone boulders were also found dispersed through the lower till station. The till was found relatively uniform throughout the site varying only in proportion of sand and silt and density. The depth of till was slightly variable across the site but can be generally described as shallow. Typical standard penetration test results (ie. N blows per foot) were found to be 20 to 45 for the upper stratum of glacial till. Typical dry density of this till was 1926 kg/m^3 to 2006 kg/m^3 and angle of internal shear resistance was estimated as 28° to 32°. Active and passive pressure coefficients were estimated as 0.30 and 3.33 respectively. Allowable bearing pressures for the glacial till at approximately 1.2 metres depth was estimated as 191.52 kPa (4000 psf).

Ground water levels were generally considered near surface with some variation across the site. In the central section and portions of the Lingan Generating Station site, ground water was at the surface and flowing. Elsewhere on higher ridges and slopes, ground water was found at varying depth, from 1 metre to 2.5 metres. The silty tills were subject to a loss in shear strength when disturbed in the presence of water and therefore, foundations should minimize soil disturbance and wet conditions during construction. The till was judged frost susceptible in varying degree proportional to silt content. Underlying the glacial till is a sedimentary sandstone of the Pennsylvania group. It is a medium grained, grey to grey brown bedrock with coarser brown texture near the till/bedrock interface. Compressive strength for the sandstone bedrock varied from 22,000 to 29,600 kPa near bedrock surface to in excess of 103,400 kPa at depth. Generally, the compressive strength of the sandstone increases inversely proportional to grain size. Allowable bearing pressure for weathered sandstone was 760 kPa and 1188 kPa for sound sandstone.

Portions of the site, including the developed areas north of the Lingan Beach Road and in and around the Lingan Mine consist of strata of loose fill overlying the original glacial till. The fill quality varies from 400mm to 1400 mm waste rock, slag and clay surrounding the Phalen Mine MRA fan house. Typical allowable bearing pressures on the fill strata were recommended to be 190 kPa.

4.1.2 Design Criteria

The results of the initial study phase yielded a number of conclusions which regulated succeeding engineering design efforts. The general design parameters listed in section 3 above were used as the basis for the design of the MRA transmission duct. In addition, other non-quantitative criteria for duct routing and design were obvious and are stated below in no particular priority:

- maximize health and safety features;
- minimize route length;
- minimize interference with existing structures, roads, railways, and electrical wires;
- avoid privately owned lands, and where possible developed lands owned by proponents;
- minimize habitat degradation during construction, and avoid long term wildlife impacts; and
- minimize conflicts with present land-use, including third party use.

During the selection of potential routes, it was suggested that aesthetic concerns should carry some influence in the selection of both the route and the support system. On this issue the study team was unable to rationalize the varied and conflicting opinions of what might or might not offend aesthetic sensitivities of those who might observe the project structures during their anticipated 20 year life.

Residential development might encroach upon the presently zoned industrial sites with uncertain social consequences. It is doubtful whether the presence of a pollution abatement duct would be separated in the public consciousness from the coal mines to which it is connected and accordingly, it was concluded that duct development should not be separated in context from the continued development of the mines.

Notwithstanding this however, reasonable attempts were made to provide an array of routes and support systems thus providing the widest latitude for selection. Without prejudice to succeeding discussion however, it was found that routes which were largely hidden by heavy wooded growth and/or were buried, resulted in overall greater habitat destruction, land-use conflicts (present and future) and cost considerably more to construct, maintain and operate.

4.2 ROUTE DESCRIPTION

4.2.1 General

Coordinates for the principal structures along the proposed transmission duct are noted below.

	Northing (metres)	Easting (metres)	Horizontal Distance (metres)
Lingan Mine			
Ventilation Fan Stack (MRA)	N5,124,300.994	E4,610,877.451	0.000
Methane Stack (MDM)	N5,124,346.663	E4,610,927.134	67.484
Phalen Mine			
Ventilation Fan Stack (MRA)	N5,124,157.705	E461,169.142	717.342
Lingan Generating Station			
Fan Site	N5,122,979.800	E4,612,634.481	
Boiler House (northeast corner)	N5,122,877.550	E4,612,695.250	

The study team reduced the plausible routes for a transmission duct routes to any of four corridors, as shown on drawing 58613-C-03 - Alternate Routes - Plans; namely:

- South Route;
- Central Route;
- Lingan Beach Road Routes; and
- North Route.

Before a detailed description of the various routes, a brief outline of the minimum right-of-way requirements would be appropriate. The general terrain to be crossed would be rolling with no sloped areas greater than 7.3%. Much of the site is overgrown with scrub brush and new growth tree cover. With the exception of the Lingan Beach Road Route and portions of the South Route, the routes would traverse relatively undeveloped areas. The transmission duct would be approximately 5 metres wide and, with a similar width to accommodate erection and construction access, it was estimated that a practical minimum right-of-way width of 15 metres would be appropriate. A detailed assessment of such criteria should be completed based upon the final design, prior to any land acquisition.

The 1983 FSEL study report [Ref. 1] highlighted the Lingan Beach Road Route for consideration. However, the report did recognize that alternative routes may be appropriate. For the purpose of completeness, a short description of each of the alternate routes is provided.

Based upon information provided by NSPC, CBDC, Town of New Waterford, Department of Transportation and Communications (NSDOT & C), as well as the Land Registration and Information Service, the principal land owners are NSPC and CBDC. The Lingan Beach Road is owned by the Town of New Waterford within its municipal limits, and by NSDOT & C outside the Town limits. A parcel of land located immediately north of NSPC's fence and just northeast of the Lingan Beach Road was not identified as belonging to either NSPC or CBDC. Two steel buildings described earlier in Section 4.1.1 occupy this site.

4.2.2 South Route

The South Route begins at the Phalen Fan House. A breeching duct would connect the existing fan exhaust to the proposed transmission duct which would then traverse above grade in a westerly direction toward the Lingan Mine. This route would cross the Lingan Beach Road overhead and then cross the Lingan Mine methane compound passing south of the methane stack. It then would pass west of the MRA fan house exhaust stack. Breeching ducts at both the methane compound, as well as at the MRA fan stack would provide the means for additional methane-air supplies to enter the transmission duct.

The south route then travels southwest above the parking lot in front of the Lingan Mine management building. A 300 metre radius curve, beginning approximately 520 metres southwest of the MRA exhaust fan permits an overhead road and rail crossing for each of the Phalen Mine access road and CBDC's main railway line. The alignment was chosen to minimize span lengths and the number of sidings crossed. From the railway crossing just east of the junction of the mainline and Lingan siding, the route sweeps southeasterly traversing wooded terrain, crossing NSPC's right-of-way for the main electrical transmission lines supplying Lingan Mine. The route continues south easterly and begins another 300 metre radius curve, which sweeps past the edge of NSPC's ash disposal dump. At this point the south route would be adjacent NSPC's right-of-way for it's main electrical power transmission lines originating at the Lingan Generating Station.

The route crosses the ash dump access road and follows the north side of this road above the ash pipeline. The alignment would be due east where it crosses the Lingan Beach Road just north of the NSPC plant access road. The route continues due east until it reaches the proposed fan site located adjacent the coal storage access road.

4.2.3 Central Route

The Central Route as the name implies, lies between the other corridors close to the origin-destination line connecting Lingan Mine and Lingan Generating Station. It begins at the Lingan Mine fan house. The duct would connect to breeching ducts above the fan exhaust and then cross into the methane compound along a northeast alignment. Breeching duct would be located in the MDM compound where additional methane (MDM) supply would be drawn into the duct. From this point the route crosses a material storage yard overhead following along the south boundary of the Lingan Beach Road. The duct would pass under the electrical transmission lines and cross over the former mine access road. It was anticipated that the high voltage electrical power lines would be raised approximately 5 to 6 metres to provide safe clearance of the duct.

A wye connector and reducer is located where the duct from Lingan Mine joins the main transmission duct from the Phalen Mine Fan (MRA). The route deviates from the south Lingan Beach Road Boundary and follows a tangent (straight line) segment heading southeast crossing the former Phalen Mine access road and the CBDC No. 5 rail siding. South east of the railway the route crosses scrub terrain and scattered trees until it crosses the ash disposal effluent return line and an overhead crossing of Lingan Beach Road. The route parallels the north side of NSPC plant access road crossing above another site road and terminates at the planned duct fan site.

4.2.4 Lingan Beach Road Route

The text printed in FSEL's 1983 study report [Ref. 1] is the basis for the brief descriptive text that follows. No attempt was made to improve this route or rationalize its characteristics beyond its inherent merits.

The fan house at the Lingan Mine is approximately 2.8 km distant from the NSPC Lingan Generating Station. The preliminary route location is shown on drawing 58613-C-03. The initial 1.9 km generally follows the north side of Lingan Beach Road from the mine; the remaining 0.9 km towards the east departs from the highway and is located on the site of the generating station.

The western portion of the duct runs on the north side of the highway, which will permit easy access for construction. The south side of the highway has been avoided initially due to the existing mine facilities: these include several rail lines, roads, buildings and underground utilities, with the storage yard extending virtually to the highway. Much of the proposed duct route on the north side is approximately 3 m below the top of roadway, thereby allowing an above ground pipeline to be less visible. The area is largely grass-covered with some bushes. To accommodate the Phalen Mine, a short run of feeder duct is shown exiting from the Phalen Mine discharge point, to connect with the transmission duct.

The transmission duct continues along the north side of the road, with an alternate route indicated on the south side. The alignment is proposed to depart slightly from the roadway into approximately 150 m of spruce woods. The remaining border of trees would enhance appearance as well as serving as a wind break. Most of the route is covered with low bushes, with some grassy areas.

The alternate route would avoid the private property and wooded area, but involves additional crossings of the highway and an access road to the ash lagoon dyke. It would efficiently use the land by utilizing the "corridor" between the highway and the CBDC railway. The alternate route also crosses a borrow pit area, believed to have most of the over-burden removed, which is near the corner of the ash lagoon.

The last section of transmission duct is located on NSPC property. The proposed route crosses spur No. 5 railway twice and includes two road crossings. All the crossings are proposed to go underground, especially since the railway is located atop 2-5 m high embankments. The alternative duct route is shown staying near the highway on the east side before crossing the former Laffin farm area. The alternative also includes two rail crossings, but involves an additional road crossing. However, only one of the rail crossings is across the busy spur #5 track used for coal delivery, which could be advantageous for construction. Both proposed routes terminate at the proposed duct fan location.

4.2.5 North Route

The North Route originates at the Lingan Mine MRA fan house following a path mostly north of the Lingan Beach Road and terminating at the suction fan at Lingan Generating Station.

From the Lingan fan house the duct crosses the MDM compound south of the MDM exhaust stack. Breeching ducts provide for the supply of MDM into the duct. From that point the route sweeps northeast across the material storage yard following the general alignment of the CBDC fence. The duct then crosses above a tailings disposal dump access road. This route avoids the high voltage power lines supplying the Phalen Mine MRA fan and skirts past the fan house compound to the north crossing CBDC's explosives cache access route. A wye connector and reducer is located at the junction of the Lingan-Phalen lateral and the main line. From this point the route traverses light scrub and wooded terrain following a slightly southeast alignment, northeast of a small ridge. The duct then follows a 1,000 meter radius curve and leads to the Lingan Generating Station just 120 metres north of the planned duct fan location. Along this circular segment the duct would cross a local access road and the CBDC No. 5 rail loop. The final alignment of the route follows the oil pipe lines adjacent the coal storage access road.

4.2.6 Route Selection

The four routes described above have significant differences in alignment, terrain covered and impacts on existing and future land use. Modifications of these routes were of course possible but not without substantially increased costs. For instance, some consideration was given to routes which would traverse over the ash lagoon and/or one or the other of the two CBDC coal mines. Disruption of existing operations, both during and after construction, as well as perceived high cost, ruled out further consideration.

The four routes identified represent therefore the range of possible route alternatives which may be considered rationally. A brief comparison of certain relevant features of each route is provided below. While the list of characteristics is not exhaustive, it is believed to be sufficiently comprehensive to permit a rational basis for selecting the preferred route.

Table 4.1 - Summary of Duct Route Attributes

Route	**South**	**Central**	**Lingan Beach Rd.**	**North**
Criteria				
Length (m)	4359	2629	3143	2675
No. road crossings	2 Hwy/5 local	2 Hwy/3 local	4 local	1 H/3 loc.
No. rail crossings	2	2	2	2
No. power line crossings	2 HV/7 dist.	2 HV/6 dist.	2 HV/4 distribution	3 dist.
% cleared lands	60%	60%	80%	80%
% developed lands	30%	45%	100%	30%
% light scrub lands	30%	15%	15%	45%
% wooded lands	40%	40%	0%	0%
Indexed Construction Cost Units	14,000	8,600	10,100	8,400

The indexed "costs" presented above are comparative in nature and were intended only to provide a means of assessing the relative merits of each route. Indexed construction cost units are based on 3 units/m for ducts, 100 units/powerline crossing, 20 units/distribution line crossing, 100 units/highway crossing and 50 units/access road and railway crossing.

It can be seen clearly from the table that the South Route would not be appropriate due to the extreme length. It also passes through wooded terrain and future residential areas west of the study site. The indexed cost reflects the accumulated overall negative impacts of this route; therefore the South Route was assessed as unacceptable and abandoned from further consideration.

The Lingan Beach Road Route offered marginal benefits with respect to construction access. The location adjacent the highway could influence snow drifting in some sections unless it were fully or partially buried. Problems associated with burial included: environmental degradation; increased construction cost and maintenance problems associated with duct drainage, etc., further add to the detrimental aspects of this route. In addition, the potential for damage due to run-away vehicles or vandalism must be considered.

At the time of the 1983 study report [Ref. 1], an additional issue was raised related to private land owners' access along the road. At that time, a number of parcels of land fronting the highway were understood to be privately owned. However, information collected from CBDC, NSPC, and LRIS indicate that such parcels have since been acquired by CBDC with the exception of one parcel located north of the NSPC site boundary and bounded by the highway.

Finally, the Lingan Beach Road Route would require the transmission duct to pass under 2 high voltage power lines supplying power to the Phalen Mine MRA fan house. Additionally, 4 local distribution power lines and/or telecommunication lines would be crossed. Relocation of these services to preserve safe clearances would require significant expenditures.

Notwithstanding its merits, the Lingan Beach Road Route was considered to be the second most costly route to develop. Accordingly the Lingan Beach Road Route was assessed overall as unacceptable and abandoned from further consideration.

The Central Route lies close to the origin / destination straight line between the Lingan Mine MRA fan house and Lingan Generating Station Boiler House. It falls within a fairly narrow corridor constrained by existing facilities of the Lingan Generating Station, the ash lagoon, CBDC railway, Lingan Beach Road and of course the Lingan Mine facilities. Its overall length, including the Lingan Phalen lateral, would be 2,629 metres, thereby making it the shortest route of the four defined routes. Much of the route southeast of the ash lagoon traverses heavily wooded areas, scrub and bog. West of the ash lagoon, the route must traverse largely developed terrain currently occupied by roads, railroads, and mine buildings. This route requires two major highway crossings, one at the Lingan Phalen lateral, and one at the entrance to the Lingan Generating Station. The Central Route passes under two high voltage transmission lines supplying the Phalen Mine MRA fan house, thereby requiring relocation, (probably elevation) of the conductors on new timber poles. The remaining 6 local distribution power lines and/or telecommunication lines crossed along the route would require relocation (probably duct encasement) underground to preserve safe and reliable local utility services.

The North Route lies almost entirely north of the Lingan Beach Road upwards of 150 metres from the travelled way. Its only highway crossing would be located just east of the Lingan Mine along a curved section of road. The crossing point was selected to provide for the maximum intersection angle. This route does not interfere with the high voltage electrical lines in the area, however 3 local distribution lines would have to be crossed (i.e. two at the highway crossing and one at Lingan G.S.). A total of 4 local access roads (i.e. 2 CBDC, and 2 NSPC) would be crossed and, like all other routes, the CBDC rail lines would be crossed twice. At 2,675 metres, this route would be 1.5% longer than the Central Route but would require fewer bends and fittings. Due to fewer road/rail/power line crossings however, the indexed cost of the North Route would be almost 2.5% less than the Central Route indexed cost. Overall therefore, the Central Route and the North Route offer approximate parity in quantitative terms. No substantial bias in favour of either of these routes was identified and therefore the final route selection was based on a value assessment of the relevant marginal qualitative aspects of the remaining routes.

The principal draw back with the Central Route was coincident with one of the principal advantages of the North Route, namely latitude of route alignment. The Central Route would be significantly constrained within a narrow corridor offering few opportunities to refine the alignment without unacceptable impacts on developed areas. The North Route, on the other hand, has the advantage of considerable latitude of relocation should further design optimization so warrant. The Central Route traverses some particularly poor terrain just southeast of the ash lagoon, while the North Route would traverse good to excellent terrain throughout. The Central Route offers difficult construction access over about 40% of its length while the North Route would have only about 20% difficult access. The Central Route would probably not interfere with any third party land owners while the North Route would require a crossing of the privately owned parcel north of the Lingan Generating Station fence. As a final point, the North Route would be perceived to offer the least objectionable duct alignment in relation to overall environmental degradation and habitat destruction. Furthermore, the North Route offers the better alignment to minimize observation from publicly accessible vantage points along the Lingan Beach Road.

Any of the above noted observations cannot in themselves justify the selection of one route over the other. However, taken together, the cumulative net marginal benefits of the North Route exceed those of the Central Route and outweigh the merits of all other routes. Accordingly, the North Route was selected for further study. The precise alignment chosen was based on all information available to the study team. It is anticipated that, as the project advances toward final development and implementation, there may be justification to modify the geometric alignment indicated on the drawings, however such realignment would be nominal in terms of construction cost impacts.

4.3 DUCT DESCRIPTION AND SUPPORTS

4.3.1 General

In order to transport the required volumes of mine methane in an effective and reliable manner and in order to minimize operating costs to near optimum limits, it was determined that pneumatic friction losses should be minimized and bends and transitions should be reduced to the fewest reasonable number.

The major constraints along the North Route are the road and rail crossings. Generically, there are two possible solutions to such crossings, namely, (i) aerial support overhead and (ii) burial under the road bed. A buried road/rail crossing would complement a transmission duct which would be buried along its full length, while an aerial support would be compatible with above ground systems.

A preliminary analysis of the benefits and costs associated with each method of crossing indicated that the buried crossing would result in substantial service interruptions during construction; increased long term maintenance effort to dewater the duct; increased energy losses due to sharp bends; increased environmental degradation during construction and considerably more construction/operating costs. Of particular significance, the potential buoyancy of a large buried duct would mandate the construction of expensive restraints against uplift forces. This latter point virtually eliminated burying the duct as an economically viable support solution. Some duct materials would be appropriate to a buried (or partially buried) approach while others would be appropriate to an aerial support system.

The following construction materials were considered for the proposed transmission duct:

i) Concrete - cast-in-place pipe (CIP)
    - precast pipe
ii) Fibreglass
iii) Wood stave
iv) Aluminum
v) Steel - welded steel pipe (WSP)
    - corrugated steel pipe (CSP)

Each of the above noted materials is discussed below. Only circular or near circular cross sections were considered appropriate for this application in order to provide reduced pneumatic losses and reduced construction costs. Other sections, such as elliptical, box, or horseshoe sections were abandoned as impractical and expensive during the initial stages of the study.

4.3.2 Concrete Duct

Cast-In-Place

It is clearly impractical to support a concrete pipe above grade due to the substantial costs associated with supporting dead loads. Accordingly, at-grade or buried support would be considered appropriate due to the relatively high strength associated with either the cast-in-place or precast duct section. A CIP duct supported at-grade would essentially follow the natural terrain except where required to cross under existing roads and rails. The profile of the duct would be somewhat irregular due to the changes in topography as well as the sharp bends at crossings. This would induce losses in addition to internal friction losses. In order to accommodate expansion and contraction of any concrete supported at-grade, expansion joints would be required at regular intervals along the route (thermal expansion /contraction would be about 15% less than that expected for steel).

For full burial, nominal cover of fill over the 4800 mm diameter buried duct, at least a 6 metre deep excavated trench would be required. The anticipated buoyancy in this situation would amount to approximately 150% of the self-weight of the pipe, if groundwater were near surface. While buoyancy may not represent a significant issue for penetrations of berms, it would warrant special foundations to resist uplift at all other areas where groundwater may be elevated. The minimum wall thickness required for a 4800 mm diameter duct would be approximately 420 mm and would be 355 mm for a 4000 mm diameter duct.

The circular pipe section would be supported on footings founded below frost susceptible soils near surface. Little, if any, ground water infiltration would be anticipated if special provisions for water-proofing were included at the buried section crossings. Small sumps would be appropriate to collect any liquid which may flow to the low points along the duct.

Precast Concrete

Precast concrete pipe sections are not commonly manufactured in 4000 mm and 4800 mm diameter sizes. However, it was understood that sections of these sizes may be manufactured at the site if special provisions for handling and transportation were adopted. The sizes anticipated would be impractical to transport by road and rail due to the width restriction.

Costs associated with the full burial option for placement of a single cross-section duct were estimated to be greater than $ 6,000/metre to supply and place the 4800 mm diameter duct and $4,900/metre for the 4000 mm diameter duct. The high relative costs associated with the concrete duct alternatives ruled out further consideration of this material.

4.3.3 Fibreglass Reinforced Plastic Duct

Fibreglass reinforced plastic (FRP) duct cannot be fabricated locally in the diameters required for this project. Based on enquiries by the team to the principals of local and regional fabricators of fibreglass pipe, it was determined that (i) the wall thickness required for strength would result in very high relative costs and unacceptable amounts of differential thermal expansion and contraction and (ii) the diameters required cannot be fabricated at this time, either on site or at a central manufacturing facility.

Notwithstanding this, principals of Beetle Plastics Inc., of Ardmore, Oklahoma were contacted. This company acquired the assets of the now defunct CorBan Division of Industrial Products Group of Fibreboard Corporation, Tampa, Florida. The company has the capability of fabricating the 4000 mm and perhaps 4800 mm diameter ducts on a special order basis from filament wound fibreglass reinforced trapezoidal rib-wall pipe. Circumferential rib stiffeners would be installed at 1000 mm nominal spacing along the duct axis, with duct lengths up to 18 metres.

Based upon initial enquiries relating to technical and economic feasibility, the approximate construction cost of a 13 mm wall thickness FRP duct on aerial supports was greater than $6,500/m. A buried duct alternative would cost significantly more than aerial support. A major source of the high cost was for transportation of the large duct sections from the US manufacturer. In view of the excessive cost of this alternative, and despite the advantages of FRP in regard to weight, frictional coefficient and dimensional stability, FRP duct was abandoned from further consideration for this project.

4.3.4 Wood Stave Duct

A wood stave duct of 4800 mm diameter and 4000 mm diameter was deemed technically feasible to construct on the site. The inherent advantages of such a system include ease of construction access, reduced need for skilled labour, potential for utilization of local timber species and superior durability with reduced thermal expansion/ contraction due to temperature. Wood also has the marginal advantage of relatively low thermal conductivity. A number of serious deficiencies with a wood stave duct include reduced air tightness due to infiltration around staves. This latter characteristic would be particularly problematic due to the negative pressures expected within the duct and the lack of a continuous source of moisture which would induce the wood staves to swell and thereby seal.

During research for this study, the team found only one project of a scope similar to the proposed, namely the 4928 mm diameter, 688 metre long wood stave "Superduct" completed in July, 1972 for Weyerhaeuser Canada ltd. at Mission Flats near Kamloops, British Columbia. That pressure creosoted wood stave duct connected a new bleached kraft pulp mill expansion to a new 64 metre high vertical stack constructed 207 metres on a hillside above the valley floor where the mill was located. The use of wood stave was particularly appropriate there due to the highly corrosive and abrasive nature of the mill emissions. The use of a timber stave duct would be possible for the proposed transmission duct; however, there are few merits for its application. The MRA stream is not considered corrosive or abrasive. The life span of the project would not justify the use of timber for reasons of durability. Site access and availability of skilled labour at or near the site do not warrant the need for "low technology" materials solutions.

On the basis of discussions with principals of Canbar Products Ltd. of Waterloo, Ontario, who specialize in wood stave construction, it was estimated that construction of a 4800 mm diameter and 4000 mm diameter wood stave aerial or supported duct would be approximately $5,800/metre and

$5,800/metre respectively. In view of the relatively high construction cost and the unacceptable infiltration, the use of wood stave duct was abandoned from further consideration.

4.3.5 Aluminum Duct

Fabrication of a 4800 mm diameter and 4000 mm diameter duct was found to be of doubtful technical feasibility. Various concepts were considered at early stages, including corrugated schemes. However, there was little technical merit or justification for using aluminum for the transmission duct; thermal expansion and contraction would be almost 97% greater than steel and aluminum lacks the strength to economically resist wind and/or earth pressures expected with either aerial or buried options. Its cost and relatively low strength virtually prohibited its use for any but special applications where low dead weight was of paramount concern. The relative costs of an aluminum duct were again quite high and not comparable to other materials considered. For these reasons therefore, use of aluminum was abandoned from consideration.

Due to its low weight in comparison to most other available materials the use of aluminum box truss and square ducting was considered for use on the existing Lingan Generating Station Boiler House in order to avoid the probable need for structural steel reinforcements of the existing structural framing (see section 7 below).

4.3.6 Steel

There were three possible steel duct systems which were considered applicable to the proposed project, namely:

i) Welded Steel Pipe (WSP)

ii) Reinforced/Stiffened Plate Steel Pipe
iii) Corrugated Steel Pipe (CSP)

The third alternative was considered a somewhat specialized variant of the second, and conceptually was deemed to offer the better prospects for cost savings, based on findings in the 1983 study report [Ref.1].

The preliminary design of a stiffened steel plate pipe fabricated near site from stock plate would require the use of sophisticated finite element analysis techniques which was considered beyond the scope of this study. There were no examples of comparable projects utilizing stiffened plate pipe found in the literature while researching this study. Despite this, the use of such pipe was considered technically plausible. However, based on best estimates, its cost could not be less than the corrugated steel pipe alternative, primarily due to higher labour cost associated with manual welding and cutting. Fabrication with automated equipment at high volume facilities would undoubtedly result in reduced initial fabrication cost; however, the very high cost of transporting the bulky pipe sections would be prohibitive. Accordingly, stiffened steel plate pipe was not retained for detailed consideration.

Of the two remaining steel pipe types (i.e. WSP and CSP), WSP was considered to be more costly than the stiffened plate pipe and CSP less costly than the stiffened plate pipe. While these alternatives are clearly not comparable in overall cost, it was determined that there are comparative advantages of each option.

4.3.6.1 Welded Steel Pipe (WSP)

The obvious disadvantage compared to corrugated steel pipe would be the wall thickness required for structural stability and serviceability. In order to maintain minimum rigidity for handling and service conditions, a minimum wall thickness of 16 mm and 14 mm would be required for the 4800 mm and

4000 mm diameter ducts respectively (i.e. 3 to 6 times that for CSP). These thicknesses exceed those required for service criteria such as wind loads and internal pressures.

The use of WSP under positive pressure would be excellent and its potential for long self-supporting spans makes it ideal for use with such applications. The relatively heavy section would warrant the use of heavy lifting equipment and would slow construction progress. The relatively high thermal coefficient of linear expansion for steel (11.7 x 10^{-6} m/m/degree C) would indicate the need for appropriate expansion joints. However, the relatively low friction coefficient for steel would minimize friction induced pneumatic losses. The thermal conductivity of steel is high and therefore exposed sections of duct should be thermally insulated and coated to minimize corrosion.

Approximate construction costs for welded steel pipe would be $ 5,000/metre.

4.3.6.2 Corrugated Steel Pipe Duct (CSP)

As with other duct materials, the desired diameters require a trade-off between operating costs to transport the MRA and the construction cost of the duct. The operating costs would be proportional to the frictional losses created by the duct wall roughness. Of the materials considered thus far, the corrugated interior would produce the highest frictional losses. The team members could not find relevant friction coefficient data within the literature during research for this project. Manufacturers of corrugated pipe and their technical staff were equally unsuccessful in quantifying probable friction losses and there was considerable conjecture among experts on this issue alone. In view of the probable impact the duct smoothness has on system operating costs, it is strongly advised that the roughness of the corrugated duct be confirmed for the large sizes anticipated. To meet that study goal and in order to provide the anticipated necessary duct smoothness, it was assumed that an interior liner was required.

At present, the largest size of corrugated steel pipe fabricated is 3600 mm diameter. This dimension correlates with coincident restrictions on flexibility, strength and transportability. It is also consistent with norms of the construction industry for culverts and sewers. The corrugated patterns commonly available for current CSP are standardized to only a few profiles. For example, helical CSP (i.e. helical rings) in diameters from 1200mm to 3600 mm would be fabricated with a 125 mm x 26 mm corrugation while structural plate CSP (i.e. annular rings) in diameters from 1500 mm to 8020 mm would be fabricated with 152 mm x 51 mm corrugations.

Structural plate corrugated pipe can currently be fabricated to the required diameters without special conditions. Also, transportation would be relatively inexpensive as the plates can be shipped to site unassembled. By contrast, helical corrugated steel pipe must be fabricated in a specialized plant using continuous corrugation and seam forming machinery.

Initial comparisons indicated that the use of helical CSP duct offered the best prospects for reliable service at lowest life cycle costs if mounted on aerial supports. Accordingly, effort was concentrated toward the development of a preliminary design which would utilize helical CSP on elevated supports. There are no examples of helical corrugated pipe of 4000 mm to 4800 mm diameter in the literature and manufacturers were not aware of helical CSP at these diameters. Due to the specialized nature of the corrugated system, a number of manufacturers were contacted to provide technical support. Their uncompensated assistance to FSEL was rendered on a proprietary and confidential basis. The two manufacturers contacted, after months of an extended period of consideration and several discussions with the study team, expressed their confidence that helical CSP with a galvanized steel liner would be technically feasible to fabricate on-site and that such a scheme would be easy and practical to erect and operate. Their recommendations respecting details of the profile should be held in confidence and not divulged to potential competition should the project proceed to detailed development. Armtec, a division of Jannock Steel Fabricating Company from Guelph, Ontario indicated that the utilization of lined steel corrugated helical duct would be technically feasible if fabricated with the following principal features:

	4000ID	4800 ID
Helical Corrugation Profile	150 mm x 40 mm	150 mm x 40 mm
Liner Thickness (24ga Galvanized)	0.715 mm	0.715 mm
Corrugated Shell Thickness	2.8 mm	2.8 mm
Self Mass	337 kg/m	403 kg/m
Longitudinal Stiffeners	4-75 x 75 x 6 L's	4-75 x 75 x 8 L's
Safe Simple Span	15 m	15 m

Atlantic Industries Limited, of Eastern Passage recommended a similar sheet steel lined helical CSP duct of the following characteristics:

	4000ID	4800 ID
Helical Corrugation Profile	125 x 26	125 x 26
Liner Thickness (24ga Galvanized)	0.715 mm	0.715 mm
Corrugated Shell Thickness	4.2 mm	4.2 mm
Self Mass	516.4 kg/m	619.7 kg/m
Stiffeners	Nil	Nil

Discussions with the local manufacturer, Atlantic Industries Limited, as well as with Armtec, indicated that the development of an on-site (or near site) fabrication plant was considered technically and economically feasible for a project of the proposed scope. Accordingly, the proposed preliminary design was prepared on this basis and costs estimated accordingly.

Concern about infiltration of atmospheric air at the duct couplers and seams has been addressed by adding gasketed helical lock seams and with gasketed corrugated coupler band joints. Welded seams are no longer commercially available; however they can be produced at a premium cost. Based upon expert advice received verbally, welded seams would not produce a substantially superior product or be cost effective at the duct sizes anticipated. However, during the study, it was reported that a US based manufacturer has developed a welded seam corrugated steel pipe process with apparent financial success. This avenue should be explored during detailed design.

As with other duct materials, there are various alternatives for support of the duct. The above ground scheme was selected for preliminary design because of its superior characteristics with respect to:

- ease of crossing existing roads and rail lines;
- controlled profile with smooth transitions and reduced pneumatic losses;
- minimum environmental impacts for both habitat destruction and animal mobility; and
- increased immunity to vandalism.

Based upon advice from the manufacturers, the average aerial span capacities were estimated as 15 m. The ducts were designed to span simply for dead loads and continuously across supports for liveloads. Longitudinal steel angle stiffeners located above and below the duct would be joined by butt welding across duct section joints. Typical sections and foundation details are indicated in the attached drawings.

4.3.7 Duct Foundations and Supports

With the relatively low weight of the transmission duct and the relatively high lateral wind loads, the aerial support foundations must be capable of resisting compressive (ie. bearing), tensile (ie. uplift) and shear loads (ie. lateral) resulting from 1 in 100 year National Building Code of Canada (NBCC 85) wind loads. Because the height above grade of the duct varies somewhat in order to permit overhead road/rail crossings, the foundation loads vary proportionally to resist overturning forces. Accordingly, the foundations must resist load factored compressive bearing forces of up to 480 kN, as well as tensile uplift forces of up to 240 kN. Due to group loading effects, the maxima are not expected to be coincident. Wind loads would also create shear loads at the foundations equivalent to the total loads on the duct structure, namely 225 kN.

A number of foundation systems were considered during initial stages of this study including end-bearing piles or timber piles; cast-in place concrete spread footings with rock anchors and mass concrete foundations. Mass concrete and spread foundations with rock anchors were considerably more expensive than other alternatives. Both the H-pile and timber pile foundations were cost effective for those portions of the site where the depth of bedrock permitted sufficient length to develop frictional uplift resistance. Generally speaking, the only area where piles appear applicable were in the filled zones adjacent to the Lingan Mine and the fill area adjacent the Phalen MRA fan house. The use of pile foundations may not be acceptable to CBDC due to potential consequences to underground mining operations and therefore an alternative foundation system was sought which would be applicable to the entire site. The use of pile foundations at selected locations should not be ruled out, however, as significant economies may be possible when selecting specific foundations at certain specific locations.

In order to meet all the requirements for duct support and to achieve economy of installation, the Foundation and Anchors Inc., of Bridgeville, P.A., S.A.F.E.

System was considered. The system consists of the installation of a steel S.A.F.E. Anchor into an auger hole of the required diameter and depth. Once the anchor flukes at the bottom end of the anchor are expanded to create a "deadman" at the bottom of the auger hole, a S.A.F.E. Foundation is mounted over the hole, attached to the anchor device and then rammed into the soil under hydraulic pressure employing the "deadman" for counter thrust. The S.A.F.E. Foundation is simply a prefabricated steel pipe pile with steel plate fins fixed full length and a base plate at the top to facilitate attaching columns. The system therefore acts as a friction pile to resist bearing, uplift and shear loads.

Essentially, the only new concept associated with this system would be the manner in which the friction pile is hydraulically rammed or pressed into the sub soil rather than the conventional method of hammering. The system permits the recording of installation forces required to install the pile and therefore considerable confidence would be achieved in determining each foundation's capacity. For additional information, a brochure has been included in Appendix 2. Because the sandstone bedrock was found at relatively shallow depth (ie. 3.6 metres plus) along the North Route, a standard foundation design was selected of 3.05 m depth (ie. deadman founded at 3.66m depth). The friction pile (ie. S.A.F.E. Foundation) component would include a 457.2 OD Schedule 20 pipe with four fins of 457.2 X 15 plate. The Foundation designation would be F2 18 10 18 and the Anchor designation would be A14 04 12. Each of the foundations can be installed in approximately 1.5 hours time employing two men and hand held equipment. The auger required to drill the 355.6mm diameter by 3048 deep holes would in normal circumstances be mounted on a light utility truck, however, for the purpose of this study it is assumed to be mounted on a tracked vehicle similar to those employed to install timber framed electrical transmission support structures.

As noted above, a particularly valued feature of the system is its capability to record actual installation force required for each unit foundation. As is advisable for friction pile foundations, it would be advisable to complete proof and performance tests at a number of locations across the route in order to validate detail design criteria. To this end, at least four to six such foundations should be installed and load tested prior to finalizing any detailed design. Savings may accrue from such foundation analysis by way of potentially reducing foundation lengths or removing the anchor device if uplift can be resisted by frictional forces alone.

4.4 CRITICAL DIMENSIONS

4.4.1 Transmission Duct

The size of the main duct was selected during the initial stages of this study and was based on preliminary calculations and available information. An optimization exercise was undertaken at that stage which resulted in selecting an optimum diameter of 4.8m. The details of this exercise are given in the Interim Report, reproduced in Appendix 5.

More detailed designs and engineering have shown that the preliminary data was inaccurate. The capital cost of the duct is greater than predicted, but also, the fan power required for various flows has increased. Thus the two main parameters have increased together and the optimal size is therefore still likely to be close to the initially selected 4.8m diameter.

At the detail design stage, alternative duct sizes and construction systems should be developed. Also, various fan systems should be included in the overall assessment. These assessments may well show that a better combination exists which should be built. The effect on overall project viability will be minimal, so the selected design is valid for this study purpose.

The feeder ducts from Lingan and Phalen mines were sized to result in similar pressure drops per unit length to those achieved in the main duct. The selected diameter was 4.0m.

4.4.2 Duct Insulation

In order to conserve the thermal energy within the transported air mass and to reduce condensation potential, a coating of spray applied polyurethane thermal insulation, protected with a UV stabilizing coating was selected. It may be applied internally, however it was considered to be more effective if applied to the duct exterior and thereby provide an added measure of protection to the duct material itself and reduced thermal expansion. In addition to other benefits related to application rate and technique, applying the polyurethane after erection would provide an air/vapour seal to the duct and permit control over colour selection of the finished structure. Also, as the extreme operating internal pressure for the duct is anticipated to be negative 254 mm water gauge (i.e. 0.36 psi or 2.49 kPa), exfiltration would not therefore be probable and the potential for "blow-off" of an exterior applied coating is considered remote.

Polyurethane insulation also has a very low moisture absorption rate, is chemically inert to pollutants and has superior bond strength and durability. Corrective maintenance would be required if acts of vandalism or other extraordinary event resulted in the loss of part of the insulating coating; however it is improbable that substantial damage could be inflicted in view of the anticipated aerial support. The painted UV protective coating would require partial replacement of up to say 20% of coverage area every 7 years. It is probable that a superior method of UV stabilization may be available, which would not require a second application and extensive maintenance during the structure's lifetime.

The combined influence of the insulating foam and the air space between the corrugated shell and inner liner was expected to offer the necessary thermal insulation. At the design flow of 380 m^3/s and a constant temperature of 13°C for MRA coming from the mine the potential for heat loss was established by determining the annual duration when atmospheric air temperature fell below 13°C. Hourly temperature data for Sydney Airport, recorded in 1988 were obtained from Environment Canada. Of the 8784 observations, 6601 were below 13°C. By computing the sum of the differences between the ambient temperature and 13°C for all observations where the temperature was below 13°C the total number of "degree.hours" below 13°C was determined. Essentially this is a numerical integration of the temperature-time graph below the 13°C datum for Sydney Airport over a one year period. The number of degree hours per annum was 76,024 °C.hr. The potential for heat loss was thus calculated to be 1.17 x 10^{14} J/yr. (1.11 x 10^{11} BTU/yr.). With no insulation, almost 100% of this energy (9.81 x 10^{13} J/yr.) would be lost.

Using a value for coal of $ 2.70 /MBtu, this equates to $215,760/yr. For comparative purposes, the capital cost and associated benefits of using polyurethane insulation (k = 0.16 BTU/hr. ft^2 °F) in increments of 12 mm were calculated. The incremental costs are essentially a linear function of insulation thickness since fixed costs mobilization and demobilization are only a small proportion of the labour and material costs. The results are summarized on Table 4.2. On this basis, 25 mm of insulation with a simple payback of less than 5 years on the first 12 mm thickness and an incremental payback of less than 10 years on the second 12 mm is an appropriate thickness. The additional cost of further insulation is not considered cost effective.

Table 4.2 - Duct Insulation Sizing

Insulation Thickness (mm)	Heat Loss J/yr (10^{13})	Saving J/yr(10^{13})	Saving ($/yr)	Incremental* Saving ($)	Incremental* Capital Cost ($/yr)	Simple Payback (yrs)	
						Incremental*/	Total
0	9.81	0	0	0			
12	2.09	7.72	170,000	170,000	679,000	4.0	4.0
25	1.04	8.77	193,000	23,000	226,500	9.8	4.7
36	0.70	9.11	200,000	7,700	226,500	32.4	5.6

* Incremental costs and savings refer to those associated with the additional last 12mm of insulation.

5.0 LINGAN MINE INTERFACE

5.1 DESIGN CRITERIA AND OPERATING CONSTRAINTS

The major system operating constraints have been listed in section 3 of this report. However, it is useful to repeat them here as succeeding sections of this report deal in detail with system control. The system must allow the MRA duct to capture up to 100% of the MRA exiting from the mine ventilation fan if the demand at Lingan Generating Station is such that all of the MRA can be used. Coincident with this condition is the requirement that the existing mine ventilation fan and ductwork system be capable of operating uninterrupted and unimpeded, regardless of the demand from the proposed MRA transport system. Operations such as air flow reversing through the mine ventilation fan should not be affected nor limited. Start-up and shut-down of the MRA transport system should not impact on existing mine ventilation operation. In addition, the system must not allow MRA with explosive air/methane proportions to enter the MRA duct.

Additional requirements are that ambient air and precipitation should be prevented from entering the transmission duct as fast as possible. The final design requirement which must be met is that the system must suit the terminal points of the existing system and conform to the layout of the mine fan area.

5.2 MINE FAN & DUCT INTERCONNECTION

The system proposed will meet these criteria and is shown on layout drawing # 58613-M-01 and on Process and Instrumentation Diagram # 58613-J-01. The existing fan outlet (4.3 m x 2.4m nominal) will have a 90° elbow attached to it to turn the vertical discharge to exit horizontally North through a new discharge duct. This new section of duct will have a horizontal lateral tee from it approximately halfway along its length at approximately 90°, which will attach to the new MRA transport system feeder duct (4.0 m diameter).

MRA exiting the mine fan will be continuously monitored to determine methane content. At a predetermined level, 2% methane in air by volume is the set-point considered appropriate for this phase of the design, an alarm will sound in the Lingan Mine control room and a signal will be sent to trip the MRA emergency damper. The emergency damper assembly will consist of an in-line shut-off damper, mechanically linked to an air inlet damper installed in the floor of the duct. When activated, the main flow will shut off and the air inlet will open. This avoids sudden excessive suction on the system in the event of MRA shutdown. The damper assembly would have to be manually reset when the MRA methane % drops below the set-point. The damper assembly will be set up in the "fail-close" mode, i.e. such that on system fail, the in-line damper closes and the air inlet damper opens. The high MRA methane content will also be alarmed at the Lingan Power Generating Station.

Limit switches will be installed on the Lingan Mine exhaust fan doors. These switches are to determine that the fan is exhausting MRA from the mine. In the event that the fan is being readied for "reverse" flow (ie. forcing air into the mine), the limit switches would cause the MRA emergency damper to trip.

A flow set manual damper is provided to allow for initial balancing of the system to ensure that the correct proportions of MRA are taken from Lingan mine and Phalen mine respectively. Detail design engineering may render this feature unnecessary, but it is included to reflect technical certainty of success, and to ensure major cost elements are all included.

5.3 MDM BLENDING

MDM blending is implemented at the Lingan Mine only. A schematic of the MDM blending diffuser is shown on drawing 58613-M-01. MRA flows from Lingan combined with total MDM flows yield a total flow of 1.0% methane. The mixture components at 50% methane (MDM) and 0.4% methane (MRA), as well as the final mixture at 1.0% methane are either well above or well below the flammability limits for methane in air @ 25 Deg. C which are 5.3% - 14.0% by volume. The mixing system must be designed to localize the zone where the mixture passes through the flammability limits.

Initially, the possibility of bleeding off a portion of the MRA to a mixing plenum was considered, in order to carry out the mixing at very high velocity outside of the feeder duct. However 40% of the MRA flow would have to be diverted in order to limit the concentration of methane to 2%. This is not practical nor does it limit the volumes in the mixing zone to minimal quantities (40% of flow is 66 m^3/s).

The scheme proposed is to diffuse the MDM into the main duct with certain concentration limits and permissive required to be met before MDM flow is allowed. The Nash vacuum pumps at Lingan mine which currently (1990) discharge MDM to atmosphere through a vent stack can operate against a back pressure of up to 35 kPa(g). It is proposed to route the MRA duct through the methane compound and locate the MRA/MDM diffuser in the MRA duct adjacent to the existing MDM exhaust stack. A backpressure valve set at 25 kPa(g) will be installed in the MDM pipe to the stack, with a pipe to the diffuser stubbed into the MDM pipe upstream of this. In the new mode, under normal operation, MDM will flow to the diffuser, with the backpressure valve opening to admit MDM to the stack only in the event of shutdown of controls on the MDM supply pipe to the diffuser.

MDM supply to the diffuser will shut down and an alarm will be generated under any one of the following conditions:

- High methane concentration in MRA from Lingan mine.
- Low flow of MRA from Lingan mine, flow switch initiated with a set point of 90 m^3/s.
- Operation of the emergency damper at Lingan mine.
- Detection of high methane concentration at detection points upstream or downstream of the diffuser.

Any shutdown of the MDM blending system would have to be manually reset by the operator.

The detectors for the above conditions are indicated on the P&ID (drawing # 58613-J-01). In addition, a shutdown of Lingan or Phalen mine fans will be transmitted to Lingan Generating Station thus giving advance warning that a shutdown of the MRA duct fan may be imminent.

90 m^3/s of MRA in the 4.0 m diameter diffuser will result in a velocity of 7.3 m/s. This is well above the flame propagation rate of 0.4 m/s for a methane in air mixture. The diffuser consists essentially of two MDM feed pipes inserted at right angles into the duct with multiple outlets drilled in the feed pipes inside the duct. The mixing zone is contained within the ductwork with no source of ignition available. The entire diffuser is located entirely within the boundary of the fenced off methane compound. This eliminates having to consider electrical equipment classification in an uncontrolled area. It also avoids retrofitting classified electrical equipment if the diffuser had been located at the Lingan mine fan.

Some thought was also given to the idea of continuously varying MDM flow in proportion to MRA flow in order to ensure a final concentration below safe limits. However it is recognized that a very reliable form of safeguard is required and that on-off control of the MDM is the most reliable choice. This is preferred over modulating the MDM flow in response to MRA flow, particularly where available MDM pressure from the vacuum pumps is low (35 kPa(g) max.) and may fluctuate. Setting the trip point for MDM at an MRA flow of 90 m^3/s will guard against nuisance tripping. Since the entire MRA transport system to Lingan Generating Station is set up to decrease flow from Phalen before decreasing the flow from Lingan, MDM will not trip until total demand goes below 90 m^3/s which corresponds to an output from Lingan Generating Station of 120 MW approximately.

The breeching ductwork at the MDM blending station and downstream for a distance of 12 metres will be constructed of annular corrugated steel plate unlined pipe similar in diameter to the 4.0 m diameter Lingan feeder duct. This type of pipe is significantly stronger that the helical corrugated pipe planned elsewhere on the duct system and can be fabricated and/or replaced with plates normally held in stock. Should a sudden pressure wave occur due to ignition of the methane-air mixture at this critical location, the annular corrugated plate pipe can:

- better withstand rapid pressure increase without distress; and,
- can be fabricated to provide for pressure relief in the case of an explosive incident; and,
- if damaged locally by such an explosive event, the pipe can be rapidly repaired with new plate sections usually available in stock

Explosion panels will be incorporated into the ductwork immediately downstream of the MRA/MDM blending diffuser. These will essentially be panels retained by shear pins and attached to the duct by security chains to prevent them becoming a hazard in the event that they blow open. The concept is shown on drawing 58613-M-01. Further sizing and design will be required in detailed design, however sufficient allowance has been carried in the capital costs.

6.0 PHALEN MINE INTERFACE

6.1 DESIGN CRITERIA

Identical criteria will apply here as in the case of the interface with Lingan mine (Section 5.1) except for the issue of flow control. Regarding this latter issue, the two MRA sources differ in that Lingan MRA will be enhanced with MDM and therefore will be the preferred source. A more detailed discussion of MRA and MDM flows is presented in section 3.

6.2 MINE FAN & DUCT INTERCONNECTION

The system proposed is the same as for Lingan (Section 5.2) except for the geometry of the initial connection to the mine fan, the absence of MRA/MDM mixing and the use of an actuated flow control damper. This damper is to ensure flow of MRA from Phalen mine diminishes to zero in response to diminishing demand before any decrease in flow of MRA from Lingan occurs.

The existing fan horizontal outlet duct (4.5 m x 4.1 m nominal) which points south will be extended. A lateral tee will be attached to this extension with a turn of 90° -110° to allow connection to the MRA transport system feeder duct (4.0 m diameter). This feeder duct will tee into the main transmission duct from Lingan Mine to Lingan Generating Station (4.8 m diameter). Flow from the mine fan will continue unimpeded straight out through the fan outlet extension in the event that demand for MRA is less than the quantity being exhausted by the mine fan. The system is shown on layout drawing no. 58613-M-02 and on the Process and Instrumentation Diagram no. 58613-J-01.

Methane monitoring of MRA from the mine and the emergency damper which shuts off MRA and allows air entry, will be the same as at Lingan mine.

(Section 5.2) The MRA high methane content shut down signal will be sent to both Lingan Generating Station and the Phalen Mine control room alarm panels. Limit switches will be installed on the mine exhaust fan to monitor reverse air flow, in a similar fashion to Lingan. These switches would trip the Phalen emergency damper.

The pressure in the ductwork system at the junction of the feeder duct from Phalen and the feeder duct from Lingan Mine to Lingan Generating Station (which will normally be less than atmospheric) will be the control set point for the Phalen MRA flow damper. As the boiler control systems at Lingan Generating Station respond to decreasing combustion air demand and the MRA duct fan flow decreases, this will cause the differential pressure in the ductwork between this junction and the duct fan to decrease. This will cause the absolute pressure in the duct at this junction to increase. The reduced suction will start to diminish flow from both Lingan Mine and Phalen Mine.

In order to avoid this, the flow control damper at Phalen mine will modulate towards the closed position in response to any reduced suction at the junction point. The set point will be the absolute pressure at the junction point corresponding to 165 m^3/s of MRA from Lingan mine. This is essentially the pressure corresponding to atmospheric pressure minus the pressure loss due to 165 m^3/s flow in the ductwork between Lingan mine and the junction point.

Once the flow control damper at Phalen mine is fully closed no further requirement for constant pressure at the junction point will be possible or necessary with decreasing flow. The remaining decrease in MRA supply will occur naturally from the remaining source, Lingan Mine, due to the continuing rise in absolute pressure at the junction (i.e. reduced suction).

7.0 GENERATING STATION INTERFACE

7.1 DESIGN CRITERIA

Again, the reader is referred to the system operating constraints listed in section 3. Of these, the main criteria are that the generating station should be able to switch to normal operation without any interruption if the MRA supply fails and no interference with normal operation should exist after switching from MRA.

7.2 DUCT FAN SELECTION & LOCATION

The operating characteristics for the fan are based upon the MRA system capacity developed in section 3. Based on a maximum MRA flow of 380 m^3/s the pressure losses for the system described on the P&ID were calculated. An internal smooth liner is assumed to be installed in all ducting. Then, a typical capacity factor for the generating station (80%) was applied to the corresponding combustion air requirements to derive an approximate fan operating profile:

Table 7.1 - Hypothetical Fan Utilization and Static Head Pressures Based on 80% Plant Capacity Factor

Flow (m^3/s)	Duration (% time)	Static Head Discharge (Pa)	Static Head Suction (Pa)	Fan Elec. Power (kW)
380	20	870	-2,370	1,658
335	46	809	-2,090	1,400
293	16	759	-1,820	1,247
251	11	716	-1,540	1,144
209	07	679	-1,340	1,035

Fan vendors were then presented with the fan utilization data in order to size a base case variable inlet vane (VIV) controlled fixed speed system. This exercise resulted in an installed fan capacity of about 1,700 kW. The fan power consumption figures at various flows shown on table 7.1 were calculated from vendor information.

CBDC and NSPC use centrifugal fans for mine ventilation and boiler forced draft services. Based on this and the fact that these are the proven type of fan for this application, the outline specification for purposes of enquiries for the study was based on a centrifugal fan. Information was requested for VIV control, electrical variable speed control and fluid coupling control. Follow-up enquiries were also made for axial fans with variable pitch in motion (VPIM) control.

The quality of information available from manufacturers of electrical solid state variable speed drives & control systems was limited and contrasts greatly with the quality and speed of responses from fan vendors. This is partly due to the fact that this is still a developing technology, especially for 4 kV systems. It is also a reflection of the fact that these drives must be engineered for each application of this size. Due to the wide range in capital costs quoted for equipment offering similar performance, a detailed study of this topic in its own right would be required before committing funds. The additional installation and maintenance costs associated with variable speed drives would have to be included if these drives are considered during detailed design.

Since the primary purpose of this study is to check overall feasibility based on reasonably conservative designs, the analysis of fan options is not exhaustive. The approach taken was to establish basic technical feasibility and then include information on other techniques which may be selected later during detailed design to further improve the project viability.

For these reasons, the capital costs and energy consumption figures associated with a centrifugal fan with variable inlet vanes were regarded as more reliable and were carried for the project overall feasibility analysis.

The fan arrangement considered is a double width double inlet design, arrangement no. 3 with the fan rotor supported at both ends. This is the basic arrangement for most power plant F.D. and I.D. fans and is also commonly used for mine ventilation fans. Overhung rotor designs with single inlet have been used previously for mine ventilation applications in this size, but have been prone to vibration problems. The fan will be located as indicated on drawing no. 58613-M-03. This was determined to be the best location available where the fan foundation can be installed without disrupting existing underground services.

7.3 DELIVERY DUCT DESIGN & ROUTING

There were few options available for routing the delivery duct from the chosen duct fan location to the FD fan intakes near the top of the boilerhouse. Existing structures such as access roads; utility buildings; out-door storage areas for coal and other consumables; conveyor gallery; underground cooling water piping and yard piping; grease pits; precipitators and stack breeching, all contribute to make the potential routes very congested.

The study team found no viable alternative to an aerial supported delivery duct route. Potential routes considered included: Alignments above and below the existing coal conveyor gallery; alignments above the existing boilerhouse roof and alignments overhanging and along the perimeter of the Boiler House roof. Due to the size of the proposed delivery duct (i.e. 4800 diameter), it was concluded that unacceptable potential snow drift surcharge loads would be applied if the duct were mounted on existing roofs. Current building codes require that substantial snow loads be provided for unless shown by detailed analysis that snow drifting is not possible. Such detailed analysis was not within the study mandate at this time, however should the project proceed to detailed design, a roof mounted duct may be re-considered.

The route that was selected for the study will not induce substantial surcharge loads upon existing power plant buildings and is intended to minimise renovating and/or reinforcing existing structures. From a pressure loss perspective, this route is optimum, as it offers the most direct route with fewest bends and fittings. Its orientation to the existing plant's orthogonal grid lines represents a compromise of appearance in favour of construction and operating costs.

From the chosen fan location north of the main plant access road, the first leg of the delivery duct would be elevated approximately 5500 above the existing road and inclined approximately 30 degrees while heading southwest toward the northeast corner of the Boiler House roof. This section of delivery duct has been initially designed as a six span continuous all steel welded 4800 ID x 16 thick pipe, complete with exterior insulation and UV protective coating. Expansion and contraction would be absorbed by expansion joints located at the top and bottom of the pipe section. This section of duct was sized to accommodate the long inclined spans necessitated by crossing the water treatment plant and coal conveyor gallery, as well as the substantial wind loads expected at the top of the boilerhouse.

Examining the available power plant drawings indicated few opportunities for ground based support of a duct routed above the east wall of the Boiler House. Therefore, an aerial mounted delivery duct supported by the existing structural frame was developed. As recent changes to National Building Code of Canada (NBCC 90) snow load requirements indicate a reduction of approximately 25% compared to NBCC 80, NBCC 77 and NBCC 75 (which were commonly consulted during the period of design development from 1976 to 1983), it was felt that the existing structure was strong enough to take the proposed additional load. This will require confirmation during detailed design.

An aluminum square duct 4300 x 4300, stiffened with a box type truss was considered appropriate for the second leg of the delivery duct. This option was proposed due to its relatively low weight. Preliminary analysis of the existing structures indicated that such a concept could be feasible, however a detailed analysis of the existing loadings and superimposed dead loads should be conducted as part of any detailed design. The duct would be mounted against the east side of the boilerhouse, below the existing fascia so as to mitigate against any snow drifting. The roof of the duct has been sloped to shed snow or rain build-up and to minimize wind load effects. The duct exterior would be insulated consistent with the other sections of duct.

7.4 INTERCONNECTION TO F.D. INTAKES

The objective of the design is to achieve a system which allows any combination of boilers to be in service and operating to maximize the use of MRA. Any shortfall in MRA supply must be made up by admitting warm boilerhouse air. Most importantly, the possibility of MRA leaking into the boilerhouse area must be minimised. The proposed design and layout is shown on drawing #s 58613-M-03 and 58613-J-01.

Four branches will be taken off the delivery duct running along the side of the power plant to supply each of the boilers. The branches will feed off the top of the duct. The principle of operation will be to operate the delivery duct at constant pressure at the point where the branches exit. This equates to approximately 870 Pa(g), (3.5 in H_2O) at the MRA fan discharge at full load. Constant pressure will be achieved by varying the capacity of the MRA fan in response to a signal from the pressure sensor located midway along the delivery duct as it runs along the outside of the boilerhouse.

The MRA will discharge to each branch through an isolation damper and a control damper feeding into a plenum which is incorporated into the top of the F.D. fan inlet duct. The control damper will modulate in response to the boiler load signal to admit MRA into the plenum. The modulation of the damper will be governed by the boiler control system so that it will not conflict with any of the criteria outlined in Section 7.1.

In the event of the MRA system shutting down, all of the combustion air for the boilers will enter through the backdraft dampers. In addition to the protection provided by the backdraft damper, the fact that the plenum will not operate at positive pressure under normal conditions will ensure that no MRA escapes into the power plant. An additional level of security will be provided by ambient methane detectors which will be located in the vicinity of the plenum at the boilerhouse side of the backdraft damper. These will alarm and shut down the MRA system to that boiler if required. These detectors could be set to alarm at a very low methane concentration.

Flow of MRA into the F.D. fan intake ducts will significantly reduce the flow of ventilation air through the building. In order to maintain an environment comparable to that which exists now, the cost of auxiliary ventilating fans has been included in the project cost estimate. These fans would be installed at approximately the same elevation as the F.D intake ducts. Using the criteria of 600 MW of power generation at a nominal 35% efficiency and 0.2% boiler radiant losses, this equates to 3.4 MW to be dissipated. If this is to be done by ventilating air, the flows required are as follows:

Boiler Room Temperature rise	°C	30	20	15
Ventilating Air Flow	m^3/s	91	136	181

For this project the cost of four thermostatically controlled ventilation fans each sized at $45m^3/s$ (95,000 ft^3/min) has been included.

7.5 ELECTRICAL SUPPLIES TO MRA FAN AND P.A. FAN MOTORS

It is proposed that a new MRA fan be fed from one of the 4160 V station busses in the Lingan generating plant. There are a number of spare switchgear cells in Station Bus A which are available in the plant. There is a 1200 Amp, 4160 V spare circuit breaker also available in one of the spare switchgear cells. Additional protection would have to be retrofitted to the spare cell and for this purpose, a Multilin-169 motor protection relay or equivalent has been proposed. The level of protection would depend on whether a solid-state variable speed drive is used as such a drive could incorporate its own motor protection unit.

To feed the motor, a 5 kV, three conductor, unshielded TECK cable will be used installed in 450 mm aluminum ladder type cable tray. It is estimated that 750 kCM cable will be required. The routing from the motor will follow the delivery ductwork to an appropriate entry point in the boiler house. Once inside the boilerhouse the routing will be along existing cable tray routes.

The motor will be a TEAAC (totally enclosed air-to-air cooled) type with starter and bearing RTDs to monitor the motor temperatures. The RTDs will be connected to the motor protection relay which would provide an alarm and signals.

Control of the fan motor will be carried out from the MRA Fan Control Panel which will be located within the boilerhouse near an exit that gives access to the fan. This panel will be the marshalling point for all instrumentation related to the MRA transfer system. Start and trip signals are fed from the control panel to the 4160 V breaker cubicle. An alarm contact from the motor protection relay will be wired to the MRA Fan Control Panel annunciator to indicate a protection trip or abnormal situation such as high stator temperature. When an alarm appears on the annunciators related to the motor protection the operator can go to the 4160 V breaker cell and determine the exact cause of the alarm.

If a solid-state variable speed drive unit is used then it would be necessary to install the associated cabinets in a clean air-conditioned room within the plant. Depending on the type of unit and manufacturer, the size of the cabinets could vary. An estimate of the size of these cabinets is 2.3m H x 4.9m L x 1m D. A suitable location would have to be found for this equipment and possibly an upgrade to the air conditioning system would be required.

Electrical power for the new P.A. fans will be derived from either motor control centres (MCC) or 600v switchgear in the power plant. Initial conversations with plant personnel indicated that there is probably insufficient capacity (and physical space) for the new starters on existing MCC busses. For that reason, the capital cost estimates include for a new MCC and it was assumed that this will be fed from existing 600v switchgear. Alternatively, each P.A. fan could be fed from 600v switchgear, via breakers fitted with motor protection relays. However, the capital cost of this alternative would probably be higher than the base estimate (i.e. a new MCC). Cost estimates for the P.A fan starters are based on 600v, 3 phase, 170 HP (150 kW) motors, two per boiler.

It must be noted that no formal load analysis of the existing power distribution system was carried out. Such an exercise is considered mandatory during detailed design and may reveal the necessity to add another 600v switchgear section fed from 4160v switchgear. No specific allowance for this latter item has been included in the detailed cost estimates.

8.0 BOILER MODIFICATIONS AND PERFORMANCE PREDICTIONS

Modifications to the Lingan Generating Station boilers are required in order to permit the MRA/MDM stream to be admitted. As this stream will be used as secondary combustion air, the interconnection between the transmission duct and the boiler FD fan intakes, as described in section 7, will be implemented. However, because the Lingan boilers derive their pulverised coal transport air (primary air) from the FD fan discharges, the presence of methane in the air fed to the mills may exacerbate the risk of mill fires/explosions.

After much analysis of the problem and discussions with reputed experts in the field [Ref.10], the study team, in conjunction with NSPC staff, agreed that the increased risk of mill fires or explosions that might be caused by an increase in the methane content of the transport air was unacceptable [Ref. 9]. Accordingly, while the FD fan intakes and MRA transmission duct were indeed interconnected, a separate source for the boiler primary air supplies was also provided for.

The interface between the MRA supply and the FD fan inlet includes provision for boiler room air to be drawn in at any time that a shortfall in MRA exists. This is discussed in more detail in section 7 above. However, the problem of avoiding MRA in the mills is less easy to resolve. The design goal is essentially to keep the primary and secondary (combustion) air streams completely separate, deriving the primary air stream from a source not containing any methane.

8.1 SEGREGATION OF THE PRIMARY & SECONDARY AIR STREAMS

8.1.1 Splitting the Air Side of the Existing Ljungstrom Air Heater

This alternative consists of converting the existing Ljungstrom air heaters to quadsector or trisector configurations. With either of these arrangements, the combustion air side of both existing heaters (Lingan boilers have two such heaters per boiler) would be modified by means of new sector plates, seals, etc. to provide totally separate primary and secondary air heater segments. Total segregation of the balance of the respective air systems would be accomplished by means of new ducting and primary air (P.A.) fans. Following this modification, MRA would be directed exclusively to the secondary side of the system and primary air to the mills would be assured by maintaining a positive primary to secondary air pressure differential at the heater outlet.

The scope and arrangement of the new materials and equipment and modifications to existing equipment required with either the quadsector or trisector versions of this alternative would be very similar. A conceptual arrangement of the trisector scheme is presented as Option A, Alternative #1 in drawing # G-MMS-587-01. In addition to the Ljungstrom air heater modifications, the scope of this modification (per boiler) would include the following:

- Two new primary air fans complete with motor drives;

- New primary air ducting, complete with all necessary expansion joints, dampers, access doors, supports (from existing structural steel) and insulation (hot air ducting only). The terminals of supply for the proposed primary air ducting system will be the outlet of the P.A. fans, the inlets of the new primary air compartments on the modified Ljungstrom air heaters and connections on the existing vertical primary air ducts upstream of the existing venturis.

- New secondary air ducting, complete with new expansion joints, dampers, steam coil air preheaters, supports (from existing structural steel) and insulation (hot air ducting only). Terminals of supply for the proposed ducting would be at the existing F.D. outlet expansion joints, the inlet and outlet of the new secondary air compartments on the modified Ljungstrom air heaters and connections to the existing horizontal main hot air supply duct. Existing hot and cold air cross-over ducts would be reused with this proposal.

- Modifications to the existing Ljungstrom heaters, in the form of double radial seals or double radial seals plus axial seals to improve sealing and reduce air leakage are included with this proposal. Anticipated reductions in leakage associated with these modifications would be approximately 19.0% for the double radial plus axial seals and 31.0% for the double radial plus axial seals.

Due to reduced secondary air and flue gas flows, future operation of the Ljungstrom air heaters will result in lower air and gas side pressure drops, slightly higher air outlet temperatures, and approximately the same gas outlet temperatures as predicted for the original contract design. No appreciable change in performance or efficiency is anticipated for future operation of the Lingan boilers following these modifications. However, due to the reduction in the free area of the secondary side of the modified Ljungstrom heaters, high air side resistance could limit the ability to achieve maximum boiler load on auxiliary fuel with only the secondary air system in service. The installation of appropriate by-pass ducts, isolation and by-pass dampers would alleviate this potential problem by allowing the use of primary air to supplement the secondary air flow.

8.1.2 Separate Tubular Air Heater

This alternative provides for the total separation of the primary and secondary air streams to the unit and would, therefore, eliminate any possibility of methane gas contaminating the air to the pulverizers. With this scheme, new primary air fans would provide the drying and conveying requirements of the existing pulverizers via a new tubular air heater and ducting. The scope and arrangement of the new materials and equipment and modifications to existing equipment associated with this alternative is presented as Option A, Alternative #2 in drawing G-MMS-587-02 and as detailed in the following description:

- Two new primary air fans complete with new motor drives.

- New primary air ducting complete with all necessary expansion joints, dampers, access doors, supports (from existing structural steel) and insulation (hot air ducting only) commencing at the outlet of the new P.A. fans and terminating at connections to the existing pulverizer hot air inlet ducts.

- New flue gas ducting complete with all necessary expansion joints dampers, access doors, insulation and supports (from existing structural steel). The proposed ducting will commence at connections centered on the top of each of the two existing horizontal gas supply ducts to the existing Ljungstrom air heaters and terminate at connections centered on the top of each of the two existing flue gas ducts to the precipitator chambers, downstream of the Ljungstrom air heater gas outlets.

- One new primary tubular air heater. The proposed heater will employ horizontal, in line tubes and vertical tube sheets arranged for gas flow over and air flows through the tubes. Tube banks will be arranged to facilitate access and cleanability and sufficient new rotary sootblowers will be provided to assure optimum availability and performance of the heater surfaces under all operating conditions. New sootblower piping, from connections on the existing sootblower steam piping system, are also included with this proposal. The proposed heater will be furnished complete with all necessary casings, doors, integral ductwork, insulation and hanger supports (from existing structural steel). Terminal of supply for the proposed heater will be at the ash hopper outlet flange.

Again, no appreciable change in performance characteristics is anticipated for the future operation of the Lingan boilers if these modifications were carried out. However, due to slightly higher design flue gas temperatures leaving the new tubular primary heater, thermal efficiencies will be slightly lower (less than 0.2% lower) than for the original contract design.

8.1.3 Separate Steam Coil Heater

A third alternative for creating a separate primary air system was also considered. This option would be similar to the previously mentioned tubular air heater alternative but would employ a steam coil type exchanger for heating the primary air and would not require any flue gas ductwork. Anticipated future performance would be characterized by high thermal losses associated with the steam condensate leaving the new heater and, due to reduced secondary air flows, increased flue gas temperatures leaving the existing Ljungstrom heaters.

Due to the anticipated reduction in thermal efficiency of approximately 0.5% for the additional heat loss in the flue gas, plus approximately 1.0% for the total steam heater condensate loss, this option has not been pursued.

8.2 FLUE GAS / AIR PULVERIZED COAL DRYING AND CONVEYING SYSTEM

In addition to the segregation of the primary and secondary air systems, the study team also investigated the possibility of utilizing hot combustion flue gases as a potential means of drying and conveying the pulverized coal at this station. The specialized technologies associated with this method of drying and transporting pulverized fuel are available and are currently in use on many low rank high ash European coal fired installations. However, the study team does not consider these technologies to be compatible with the type of fuel or equipment in use at Lingan Generating Station, and, for the following reasons, does not consider this method of operation to be suitable for this application:

- From an information search by the study team it appears that an inert medium (hot flue gas) has not been tested or used as a method of drying and transporting high volatile North American Bituminous coals with the type of pulverizing and fuel firing equipment in service at this station.

- Because of the extremely low O_2 levels present in the pulverized coal/flue gas stream entering the furnace through the burner register coal bucket and because of inadequate mixing anticipated between the fuel and secondary air streams, it is the opinion of the team that this method of operation would be characterized by poor flame stability, poor turndown and high carbon loss from the unit.

- Suction type pulverizers, such as those employed at Lingan, utilize a counterbalanced style of damper, located on the hot air inlet ducting, as the means of introducing tempering, ambient boilerhouse air to the system. Assuring a totally inert environment (i.e. no tempering air) within this coal pulverizing/transport system would require the installation of dual hot and cool flue gas extraction booster systems to satisfy both the drying and tempering requirements of the mills. Such a system would be both costly and difficult to control.

- The use of flue gas in the pulverizer system would act as a form of gas recirculation within the boiler. Higher gas mass flows and velocities associated with this recirculation would result in accelerated ash erosion rates and increased heat transfer to the convective heating surfaces. Additional heat absorbed by these surfaces could result in metal temperatures which exceed the design limitation of the existing materials and could result in reheater and main steam temperature control problems. Therefore, any modification of this nature would require a thorough reassessment of existing boiler surfacing and materials.

Blending of relatively small quantities of high temperature (i.e. 1093°C) flue gas with ambient boiler house air could satisfy the drying and transport requirements of the existing pulverizers, eliminate the need for a primary air heater and minimize the impact of the recirculated gas on burner stability, turndown, carbon loss, erosion, metal temperatures and steam temperature control. However, the availability of suitable, reliable and cost effective ducting, dampers, blending, extraction/booster and dust collecting equipment, required for such a system, is questionable.

High tempering air flows required with this system would result in reduced secondary air flows, increased Ljungstrom air heater gas outlet temperatures and lower thermal efficiencies, as was the case with the steam air heater alternative described above.

Due to the high gas temperature associated with operation of this type, the potential for overheating the pulverizer components and fuel piping and the increased potential for mill fires are areas of major concern. Particular attention would be required with such an application, in assessing and implementing the controls and interlocks necessary to assure acceptable mill temperatures under all operating conditions. The boiler supplier has indicated that, before condoning any modification of this type, a thorough assessment of anticipated performance, materials and heating surface requirements and full scale fuel burn tests would have to be carried out.

8.3 SELECTED BOILER MODIFICATION OPTION

Based on the above evaluation, the study team concluded that:

- The separate primary air heating schemes, outlined in section 8.1 of this report, represents current proven air heating technologies, employing materials and equipment with proven track records and afford a cost effective means of satisfying the project objectives, while assuring the future safe, reliable and efficient performance of the boilers.

- The various gas and gas plus air pulverized fuel drying/transport systems, described in section 8.2, represent technologies which are unproven for applications of this type and are not compatible with the pulverizing/drying and firing systems presently employed on these units. In addition, such systems could adversely affect present performance and heating surfaces, lead to accelerated erosion rates and pose serious concerns with respect to the safety, reliability and efficiency of future operation.

Based on the observations and conclusions outlined above, a separate primary air heater system, such as that proposed in section 8.1.1 above, affords the most effective means of achieving the overall objectives of this project, while assuring the future safe, reliable, efficient performance of the equipment in question. Minor changes to boiler performance and efficiency are anticipated for future operation of the boilers following the recommended modifications.

8.3.1 Description of Air Heater Modification

A number of configuration changes for the Ljungstrom air heaters were proposed and discussed at length in order to ascertain which was the most technically feasible and cost effective. The study team acknowledges the expert input provided by Howden Sirocco Canada during this exercise.

Listed below is a brief summary of comments regarding the major advantages and disadvantages of each of these air heater configurations, based on ABB-CE observations and on Howden Sirocco Canada's feedback.

1) Conversion of both existing Ljungstrom heaters to quadsectors.

Advantage:
- Low secondary to primary air entrainment (approximately 18,000 lb/hr with 24 sector conversion, double seals plus forced air) and no secondary air to gas leakage.

Disadvantages:
- Most costly option.
- Prototype in nature, as this concept has never been used for such an application.
- High secondary air side pressure drop.
- Actual feasibility has not been finalized and would require further evaluation by Howden.
- Air inlet and outlet ducting arrangement would be complicated and costly.
- Relatively high total air to gas leakage.

2) Conversion of one existing Ljungstrom heater to trisector duty and upgrading the seals on the remaining, existing Ljungstrom.

Advantages:
- Simplified primary air ducting arrangement.

- Low secondary to primary air entrainment (approximately 10,000 lb/hr, with 24 sector conversion, double seals plus forced air).
- Proven design.
- Relatively low total air to gas leakage rates.
- The modifications to the Ljungstrom heaters would be slightly less costly than for either of the other two options. However, the increased scope of primary and secondary air ducting required with this option would tend to offset these savings.

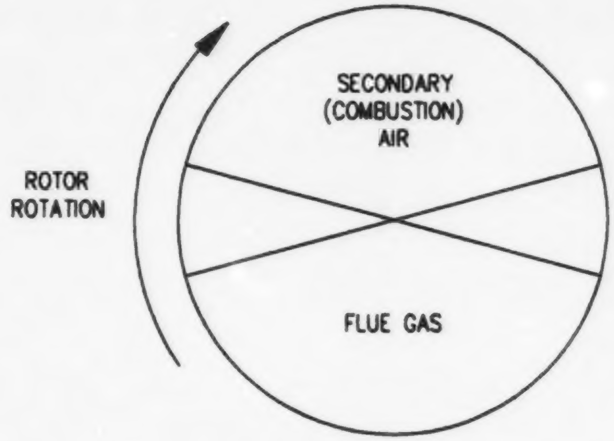
Disadvantages:- Operation and control of the combustion air systems would be difficult with this option

- High primary air side pressure drop.
- High secondary air to gas entrainment/leakage (approximately 15,000 lb/hr total, with forced air on both heaters).
- Actual feasibility requires further evaluation by Howden Sirocco Canada.

3) Conversion of both existing Ljungstrom heaters to trisector duty.

Advantages:
- Proven design.
- Less costly then quadsector option.
- Secondary air to gas leakage and secondary air to primary air entrainment rates (approximately 1,360 kg/hr and 1,800 kg/hr respectively with 24 sector conversion, double seals plus forced air).
- Balanced, workable primary and secondary air ducting arrangement.
- Reasonable air and gas side pressure drops.
- Relatively low total air to gas leakage rate.

EXISTING LJUNGSTROM AIR HEATERS (2 x 12 SECTOR)



TRISECTOR MODIFICATION (2 x 24 SECTOR)

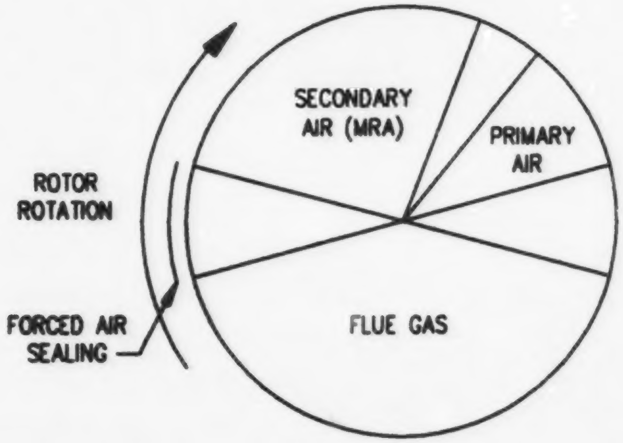


FIGURE 8.1 – LJUNGSTROM AIR HEATERS

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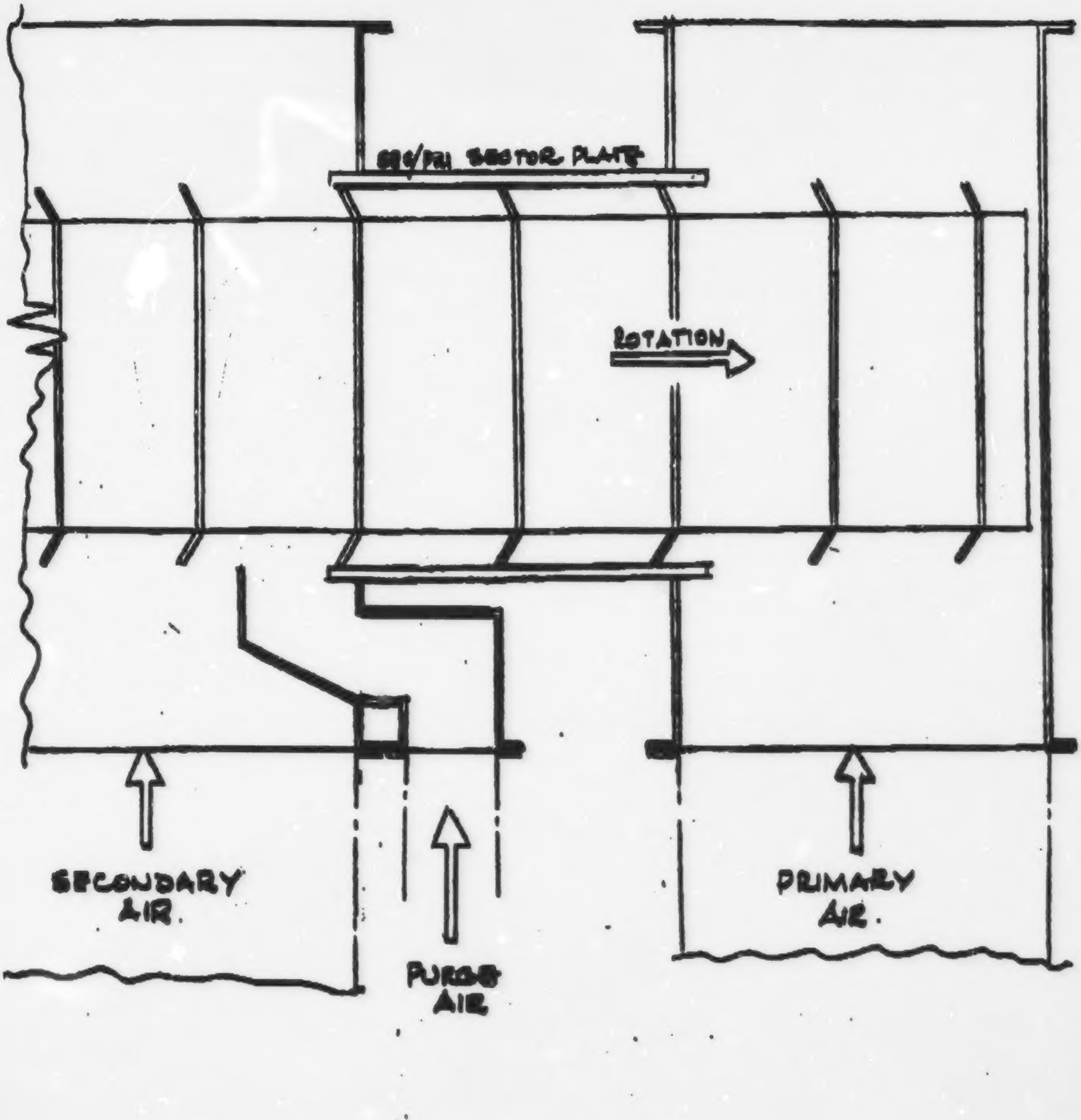
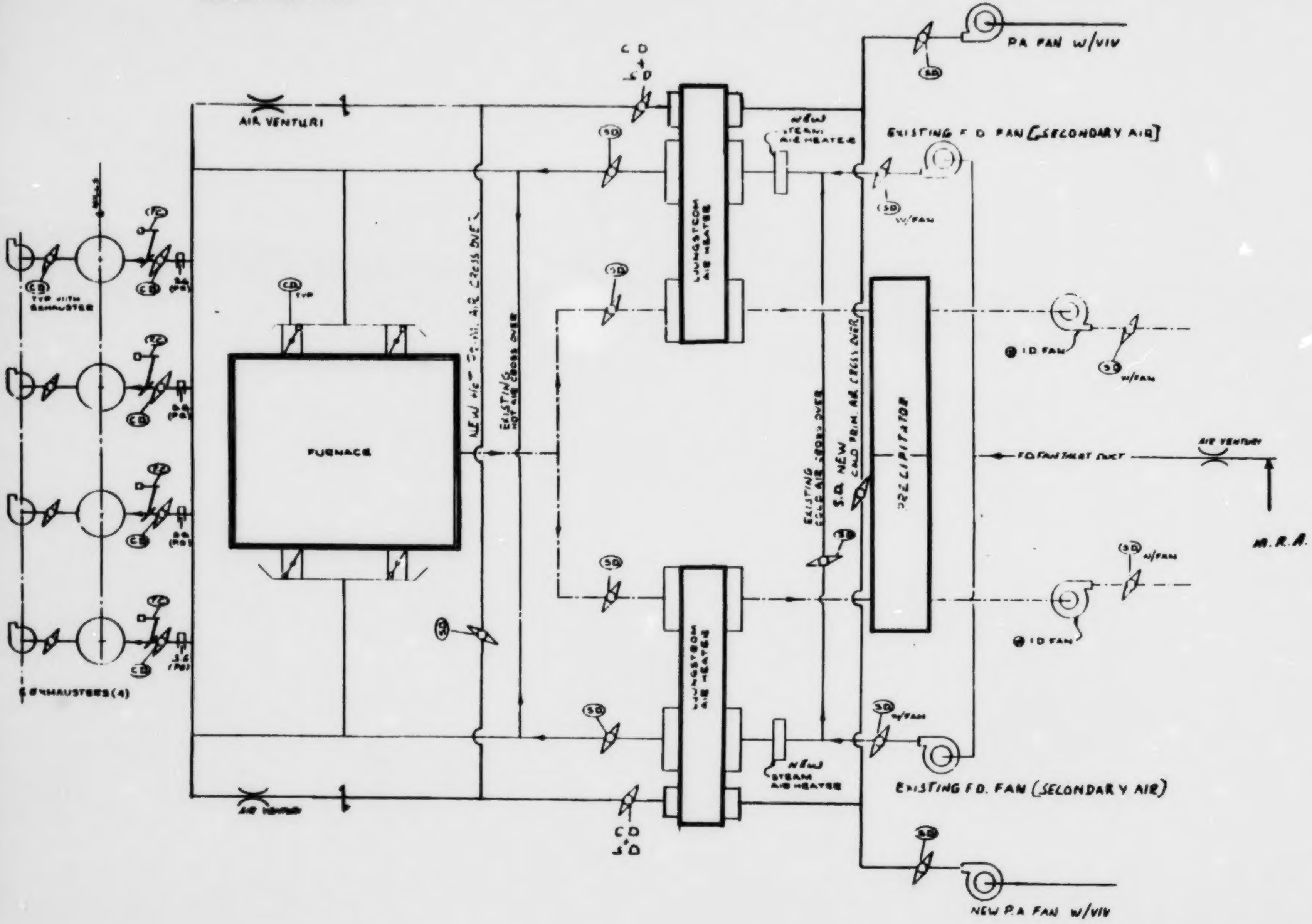


SCHEMATIC GAS AND AIR FLOW DIAGRAM
SKETCH No. 1



Disadvantages:-	Data from Howden indicates that the leakage rate from the Secondary to the Primary air will be about 1,800 kg/hr. This will result in a methane concentration of about 0.025% at the mills if only one boiler was operating. As is the case with all three options outlined herein, the ultimate feasibility of this option would require further evaluation by Howden Sirocco Canada.

With each of the configurations described above, the team considered converting the rotor from a twelve sector to a twenty-four sector unit. The increased number of sectors increases the number of seals which naturally minimises cross leakage. Selecting the best option requires optimization between the following parameters:

- cost of the air heater modification and associated ducting.
- value associated with reducing leakage of MRA into the flue gas.
- boiler performance achieved.
- leakage of primary air into the MRA stream and its effect on the total MRA which can be used per year.

This extensive evaluation exercise would form part of the detailed design phase. For the purposes of this study, and after consultation with Howden and ABB-CE, it was decided that the trisector - 24 segment, double seal arrangement would be chosen. The rationale was that it had a significantly lower MRA leakage rate and that this would offset the potentially higher capital cost. In the trisector arrangement, primary air is maintained higher than MRA so that leakage is towards MRA and towards flue gas. Leakage of MRA to flue gas is minimised because the rotor turns clockwise. Figure 8.1 shows a general arrangement of the existing Ljungstrom air heaters and also the proposed trisector modification. Boiler performance prediction studies have been based on this proposed modification. Data supplied by Howden Sirocco which relate to the selected air heater modification is reproduced in table 8.1. These data are based on each boiler operating at maximum capacity, i.e. 490.32

x 10^6 kg/hr. However, plant performance calculations have been worked out with these data reduced to reflect the lower steam flow rate of 464.44 x 10^6 kg/hr corresponding to actual turbine rated output.

Table 8.1 - Preliminary Duties, Modified Ljungstrom Air Heaters

			24 Sector Conversion - Double Seals & Forced Air
Gas in		kg/hr	676,300
Gas out		kg/hr	706,660
Air in Sec.		kg/hr	498,460
Air out Sec.		kg/hr	516,650
Air in Prim.		kg/hr	114,300
Air out Prim.		kg/hr	81,650
Air in Sec.		Deg. C	16
Air out Sec.		Deg. C	272
Air in Prim.		Deg. C	27
Air out Prim.		Deg. C	238
Gas in		Deg. C	374
Gas out (uncorr.)		Deg. C	161
Gas out (corr.)		Deg. C	156
dP Sec. Air		kPa	1.13
dP Prim. Air		kPa	0.88
dP Gas		kPa	1.06
total dP Sec/Gas	hot end	kPa	2.53
	cold end	kPa	4.72
total dP Prim/Gas	hot end	kPa	3.16
	cold end	kPa	5.10
Prim/Sec air leak.		kg/hr	5,450
Sec/Prim. air leak.		kg/hr	1,800
Sec/Gas leak.		kg/hr	1,360
Prim/Gas leak.		kg/hr	29,000
Purge Air flow to Sec.		kg/hr	15,900

8.4 BOILER PERFORMANCE PREDICTIONS

The leakage rate of secondary to primary air quoted above is about a quarter of what had been originally proposed (7,713 kg/hr) by Howden. The revision was requested because it had been recognised that the original leakage rate was unacceptably high. It was felt that the rate could be reduced to 10% of what it had been, i.e. to about 770 kg/hr and boiler performance data was calculated with this figure assumed. In theory, these calculations should be revised to take into account the revised leakage rate that Howden proposed. However, ABB-CE have advised that the effect of the leakage rate change on boiler performance calculations is minimal; therefore, considering the accuracy of other assumptions made during the study, it was decided not to adjust the figures that follow.

The chief operating assumptions for the Lingan Generation Station were defined in section 3 of this report. These assumptions play an important role in the calculation of boiler performance predictions. It was assumed that Lingan Mine will continue operations for the projected life of the proposed project and that up to 380 m^3/s of total MRA and MDM flow will be available at all times, i.e. throughout the project in-service life. Lingan Generating Station capacity factors were also assumed to be:

1993 - 2000:	80%
2001 - 2005:	75%
2006 - 2013:	65%

8.4.1 Reductions in Coal Consumption Due to Burning MRA

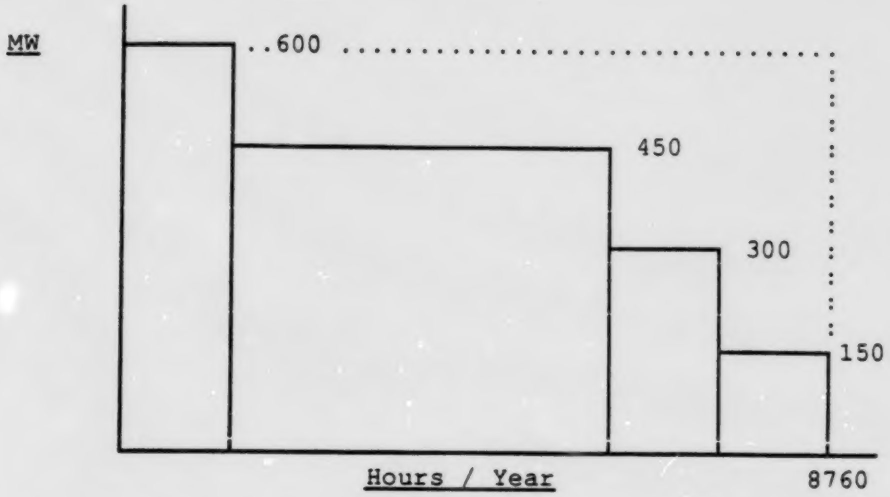
The coal offset by burning MRA is assumed to be the blend currently being used at the plant, i.e. a blend of Prince Mine coal mixed with some washed coal from Victoria Junction. A sample of this coal was analyzed by CANMET and was found to have the following characteristics:

Component	% Weight
Carbon (C)	65.90
Hydrogen (H)	4.30
Nitrogen (N)	1.30
Oxygen (O)	5.50
Sulphur (S)	3.00
Moisture	9.00
Ash	11.00

The heating value of this coal is 27,208 kJ/kg (11,695 BTU/lb.) This analysis has been used as the coal of record for the purposes of the study.

In order to simulate the plant capacity factor, an annual projection of boiler operation has been developed. This projection assumes a certain percentage of time delivering 600 MW (i.e four boilers operating), another percentage of time delivering 450 MW (three boilers operating) and similar percentages for 300 and 150 MW. A set of percentages was selected such that each set combines to give the plant capacity factors referred to above. An additional assumption has been made that when a boiler is in service, it runs at MCR.

A typical set of percentages, or percentage of time at a given plant output, can be represented as a histogram. The area bounded by the dotted line above the histogram bars reflects the energy that the plant did not generate in any one year. This area represents, for example, 20% of available plant capacity for a plant with an 80% capacity factor:



Now, the characteristics of boiler performance will be different for each bar of the histogram due to changes in methane concentration in the total MRA/MDM stream. The quantity of MRA which each boiler actually takes in is governed by the leakage rate of secondary (MRA) air into primary air and the leakage rate from MRA into flue gas. Also, in practice, all boilers will not receive the same quantities of MRA. However, as a simplification for the study, equal MRA to all on-line boilers was assumed. The changes to the concentrations of methane in MRA for differing plant demand conditions are given in the following tables:

> 542 MW

SOURCE	FLOW m^3/s	% METHANE	m^3/s METHANE
Lingan MRA	165.0	0.40	0.660
Phalen MRA	213.0	0.40	0.852
MDM	2.0	50.00	1.000
TOTAL	380.0	0.66	2.512

474 MW (one boiler out of service)

SOURCE	FLOW m³/s	% METHANE	m³/s METHANE
Lingan MRA	165.0	0.40	0.660
Phalen MRA	144.3	0.40	0.588
MDM	2.0	50.00	1.000
TOTAL	311.3	0.72	2.248

316 MW (two boilers out of service)

SOURCE	FLOW m³/s	% METHANE	m³/s METHANE
Lingan MRA	165.0	0.40	0.660
Phalen MRA	51.8	0.40	0.210
MDM	2.0	50.00	1.000
TOTAL	218.8	0.85	1.870

158 MW (three boilers out of service)

SOURCE	FLOW m³/s	% METHANE	m³/s METHANE
Lingan MRA	107.9	0.40	0.430
Phalen MRA	0.0	0.0	0.000
MDM	2.0	50.00	1.000
TOTAL	109.9	1.30	1.430

This information was integrated with the air heater leakage data, boiler performance data, as well as the defined percentages of time for each level of aggregate output, so that the amount of coal displaced by burning the methane contained in the MRA/MDM stream can be calculated. The results of this exercise are as follows:

CAP. FACTOR (%)	PLANT OUTPUT (MW)	% TIME / YEAR	COAL SAVED (t/hr)	COAL SAVED (t/yr)	TOTAL (t/yr)
80	600	60	11.08	58,236	86,789
	450	15	9.84	12,930	
	300	10	8.25	7,227	
	150	15	6.39	8,396	
75	600	50	11.08	48,530	84,310
	450	15	9.84	12,930	
	300	20	8.25	14,454	
	150	15	6.39	8,396	
65	600	35	11.08	33,971	78,845
	450	20	9.84	17,240	
	300	15	8.25	10,841	
	150	30	6.39	16,793	

It can be seen from the results above that the coal displaced does not diminish in direct proportion to the capacity factor. Thus the reduction in SO_2 and NO_X emissions is maximised, while the emissions of methane (greenhouse gas) are minimised, even though plant utilization is diminishing.

Knowing the coal savings due to MRA combustion and MRA volumes allows the remaining energy / coal consumption changes to be calculated. These include changes to ID,FD and PA fans power consumption, energy savings from reduced coal and ash handling and ventilation heating saved.

8.4.2 Fan Power Consumption Changes

The predicted reduction in FD fan power consumption is 50 kW, implying 100kW for a single boiler. This is offset by the need to install two PA fans, each consuming 150 kW. As there is no predicted change in the power consumption by the ID fans, the net power consumption change is 200 kW per boiler. For four boilers with the operating percentages defined above, the total extra fan electrical power is

Plant Cap. Factor (%)	Fan power Increase (kW)
80	200 x 4 x 0.80 = 640
75	200 x 4 x 0.75 = 600
65	200 x 4 x 0.65 = 520

8.4.3 MRA Fan Power

Power consumption by the MRA duct fan varies with the MRA flow rates through the system. Typical fan power consumption figures were presented In section 7 for the hypothetical fan utilization figures given to vendors. These figures roughly corresponded to a plant capacity factor of 80%. Thus, it has been assumed that the continuous fan power consumed over a year for a plant capacity factor of 80% is simply the weighted average of the fan powers listed on table 7.1. The relevant data are repeated here for ease of reference:

Fan Power (kW)	Duration of Time (%)
1,658	20
1,400	46
1,247	16
1,144	11
1,035	07

From these data, the weighted average fan power is 1,373 kW. Corresponding figures for lower plant capacity factors were calculated as follows:

Plant Cap. Factor (%)	Weighted Avg. Fan Power (kW)
80	1,373
75	75/80 x 1,373 = 1,287
65	65/80 x 1,373 = 1,116

8.4.4 Reduced Coal and Ash Handling

Reductions in energy consumption from coal and ash handling equipment is assumed to be in direct proportion to the amount of coal saved due to burning MRA. The 1983 study [Ref. 1] had a figure of 258 MWh/yr in savings for 26,600 tonnes/yr of coal saved thus. Extrapolating this for the annual coal saving figures developed above gives

Plant Cap. Factor (%)	Energy Reduction (MWh/yr)
80%	879
75%	863
65%	822

8.4.5 Coal Consumed in Preheating MRA

MRA entering the FD fans has to be heated by an additional amount defined by the difference between the MRA inlet temperature and the boilerhouse ambient air temperature at the FD fan intakes. The total quantity of MRA received by the plant varies with plant load, thus the coal consumed for this purpose also varies. The following sample calculation is based on a single boiler operating in a plant delivering 450 MW, i.e. 3 boilers on line:

methane concentration = 0.72%

methane volume to furnace = 0.743 m^3/s (corrected for lower leakage rates)

therefore, MRA volume per boiler = 0.743/0.0072 = 103.2 m^3/s
or 218,577 ft^3/min

temperature difference is 25 Deg. F

thus, BTUs required are 1.1 x 25 x 218,577 = 6.01 x 10^6 BTU/hr

@ 11,695 BTU/lb and 2204 lbs/tonne, this becomes 0.24 t/hr. per boiler, or 0.71 tonnes/hr. for the three boilers on line.

8.4.6 Ventilation Heating Avoided

Savings are realized from displacing air drawn into the building during winter months and which has to be heated to about 16 Deg.C (60 Deg.F) for comfort. For the Sydney area, winter air temperature is based on 8,000 degree-days and 273 winter days and is

60 - 8000/273 = 31 Deg.F

Now, 380 m^3/s is equivalent to about 805,180 ft^3/min, so the heat added (coal equivalent) is (1.1 x 805,180 x 31)/11,695 x 2204 = 1.066 t/hr

Assume that heat savings only accrue for 75% of the year; so assume 3 boilers operating. The equiv. coal figure for 360 m^3/s (3 boilers operating) is 1.004 t/hr. or 1.004 x 8760 = 8,795 t/yr.

For 80% cap. factor and boiler efficiency of 87%, the coal savings become 10,109 t/yr. At 75% cap. factor, savings are 75/80 x 10,109 = 9,477 t/yr and (similarly) 8,214 t/yr at 65% cap. factor.

9.0 SYSTEM CONTROL PHILOSOPHY

The system control system is designed to ensure the safe delivery of MRA to the power plant in quantities and concentrations required by plant operations. Process and Instrumentation diagram drawing 58613-J-01 and Logic Diagram Figure 9.1 should be referred to when reading this section.

9.1 SYSTEM OPERATING CONSTRAINTS

The major system operating constraints governing the operation, and therefore the design, of the MRA transport system have been defined earlier in section 3. The reader is referred to that section.

9.2 MRA DELIVERY - CONTROL REQUIREMENTS AND SAFETY ISSUES

9.2.1 System Safety and Protection

The operation of safety equipment to shut down MRA and MDM supply at the Lingan and Phalen Mines have been described in sections 5 and 6 above. In addition, the MRA fan is designed to shut down on any of the following conditions:

- High discharge pressure (pressure switch)
- Low suction pressure (pressure switch)
- High Fan Vibration
- High methane concentration

Methane concentration is measured at the following locations:

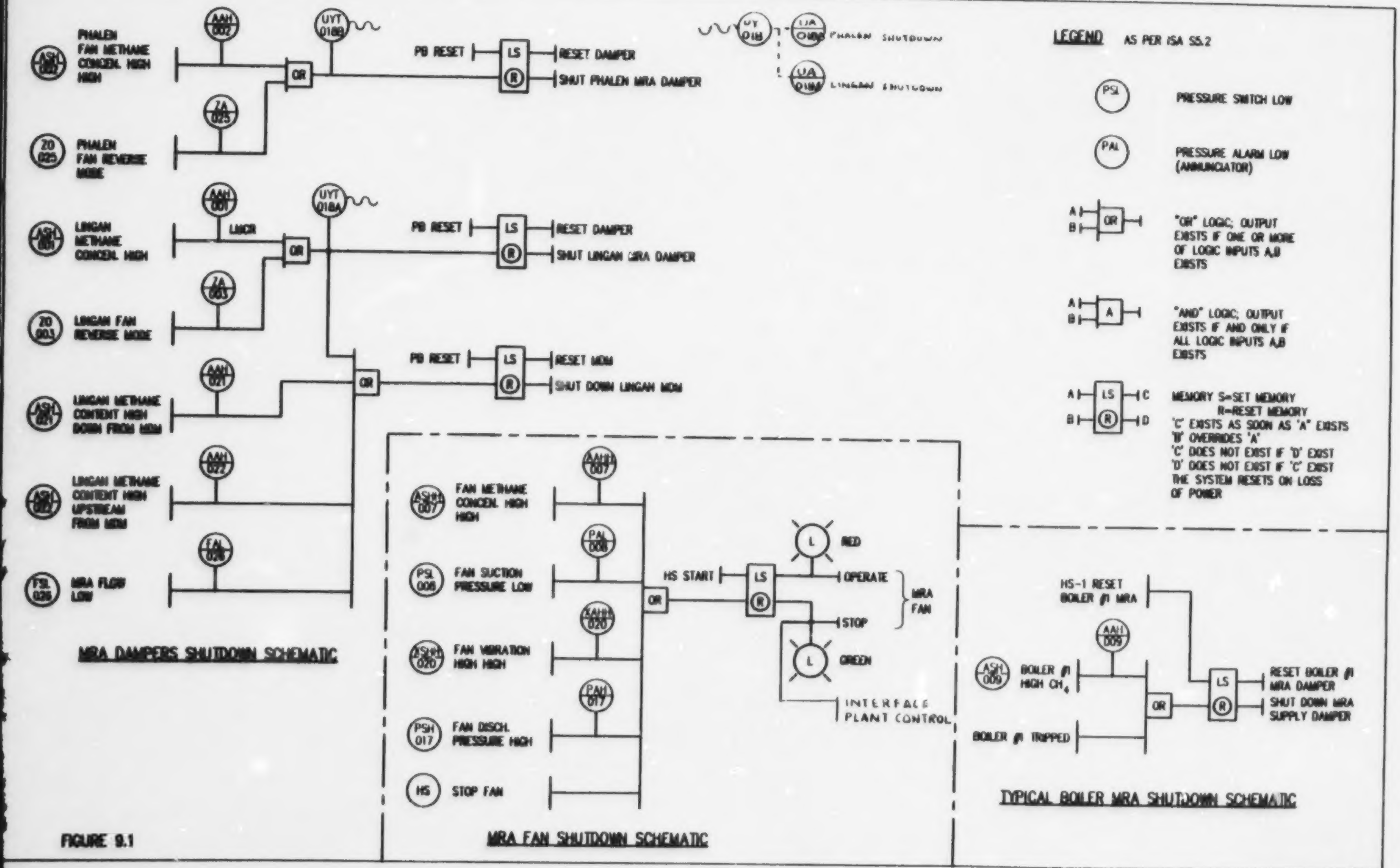


FIGURE 9.1

CAD DWG No: 58613J02
PLOTDATE: 19910125.1142

- MRA exit from Phalen Mine
- MRA exit from Lingan Mine
- MRA stream, upstream of MDM injection point
- MRA stream, downstream of MDM injection point
- MRA duct fan discharge
- Ambient boilerhouse air outside the backdraft damper at the MRA stream/ FD fan interface.

These alarms are all annunciated on the MRA Fan Control Panel. Any shutdown is also alarmed at the Generating Station Main Control Room (MCR).

9.2.2 Fan Control Scheme

The MRA fan controls are designed to provide a relatively constant discharge pressure, whenever possible, under a variety of operating conditions. In order to accomplish this, the fan is equipped with a capacity controlling device consisting of variable inlet vanes (VIV).

The fan discharge pressure is monitored with an electronic pressure transmitter. This pressure signal is sent to the discharge pressure controller which will send a signal to a signal selector and then to the VIVs so as to maintain the discharge pressure at a constant set point.

The suction pressure of the fan will also be monitored with a pressure transmitter in order to guard against abnormally low pressure. This might occur if either of the MRA emergency dampers at the mines were to be activated. The pressure signal is sent to a suction pressure controller, whose function is to limit the suction pressure to greater than a set minimum value. The controller's set point is chosen to be below the suction pressure that exists under normal operating conditions (ie. maximum throughput conditions). The controller's output is also sent to the signal selector referred to above.

If the suction pressure drops below the suction controller set point, its output signal be selected and sent to the VIVs. When this happens, the suction pressure controller will not allow the fan to bring the suction pressure below its set point, but would control at this set point. This means that the discharge pressure drops below the normal pressure and varies as a function of the suction pressure controller's actions.

If supply conditions return to normal, the suction pressure at the fan tends to rise. This causes the suction pressure controller to increase fan throughput, thus causing an increase in discharge pressure. This action continues until the discharge pressure reached the discharge controller's set point. The discharge pressure controller then takes over control of the VIVs and modulates these to maintain a constant discharge pressure.

At this point the suction absolute pressure is at or greater than the suction pressure controller's set point. However, if the suction pressure were to again drop to the suction controller's set point, this latter controller again override the discharge controller.

9.2.3 MRA Flow Metering

A volumetric flowmeter will be installed in the suction line to the fan. The primary element chosen is a standard ASME venturi. This design was selected to give an accurate indication of flowrate with a minimum permanent installed pressure loss. A differential pressure transmitter (flow transmitter) will send a signal to a mass flow computer. This computer will also accept signals from a temperature sensor inserted in the suction duct and from the pressure transmitter used for suction pressure control.

The flow computer sends out a compensated flow signal to a methane totalizer, which multiplies the MRA flow signal by the concentration of methane signal sent out by the methane monitor. The totalizer then counts the result as standard cubic metres of methane. This methane total might be used for plant energy balance calculations, for example.

9.3 BOILER CONTROL MODIFICATIONS

The impact on the power plant of an MRA transport system shutdown is great enough that it needs to be addressed. The fan shutdown signal will be brought into the Main Control Room. It will be tied to the plant control system to immediately ask for additional BTUs in the form of coal to replace BTUs lost from the MRA system. This will be done before the waste gas O_2 analyzer has a chance to detect the higher excess oxygen caused by the loss of MRA. This will tend to smooth out the process upset caused by the MRA transport system tripping.

9.3.1 Flow Control

The quantity of MRA allowed into each boiler will be controlled. This will be achieved by using the existing air demand signal going to control the FD fan dampers.

This signal will be sent out to a signal characterizer; the function of the characterizer is to have the MRA damper operate as a pre-determined function of the FD fan air demand. A proposed operating regime would have the MRA damper open only for boiler air demand greater than 50 percent; the MRA damper would open following an adjustable curve of % MRA versus total air demand.

9.3.2 Shutdown Control

As previously mentioned in section 7.4, an unacceptable ambient methane concentration next to the backdraft dampers will cause a trip of the MRA shutdown damper associated with that boiler. The existing boiler trip signal will also be wired to trip the associated MRA shutdown damper. This shutdown damper will require to be manually reset to re-admit MRA into the boiler with which it is associated.

10.0 LAND USE AND ENVIRONMENTAL CONTEXT

The intent of this section is to:

i) indicate the environmental issues or impacts, both positive and negative, that may arise from the construction and operation of the project;

ii) identify pertinent legislation, both federal and provincial, that may apply to the project; and

iii) raise any other related matter that may impinge upon or facilitate the project's implementation.

10.1 IMPACTS

The project is to locate a conduit approximately 4.8 m (16 ft. in diameter) between Lingan and Phalen Collieries and the Lingan Generating Station. Several routings are being considered. The potential environmental and socio-economic impacts, positive and negative, that may be derived from the construction and operation of the project can be summarized as follows:

10.1.1 Benefits or Positive Impacts

i) upon completion of the conduit the emission of methane to the atmosphere will be reduced;

ii) upon completion of the conduit the emission of sulphur and nitrogen oxides to the atmosphere will be reduced;

iii) during construction there will be additional employment opportunities created for the local labour force; and

iv) the implementation of the project will enhance the financial efficiency of the associated plants.

10.1.2 Costs or Negative Impacts

i) the removal of vegetation and soil to clear the conduit route, including the upgrading of any rights of way if applicable, may alter drainage flows, may create additional run off and may cause erosion;

ii) the removal of vegetation and soil as described in i) above may disrupt and degrade habitat and may create an unsightly appearance;

iii) the onsite construction of the pipeline may result in increased dust and noise levels;

iv) the transportation of debris and construction materials to and from the site will necessitate increased levels of truck traffic;

v) the construction (and operation) of the conduit may disrupt the numbers and types of animal/bird species that presently inhabit the area;

vi) any construction debris remaining after site clean-up would be a degradation of the surrounding environment;

vii) there may be actual or perceived safety risks regarding potential leaks or the combustibility of the gas in the conduit;

viii) local residents may have concerns and negative perceptions about conduit operation, safety and health derived matters; and

ix) the visual impact of a 4.8 m (16 ft.) conduit on the landscape may be less appealing than what presently exists.

10.2 RELEVANT LEGISLATION

Comprehensive environmental legislation is a recent development at both the federal and provincial levels of enactment; it is a complex area of law and one that is evolving rapidly. In general terms there are at both legislative levels:

i) omnibus acts which aim to establish procedures to ensure the identification of all environment impacts or to establish principles or standards of general application; and

ii) acts of specific application which provide standards, procedures, etc., for a specific purpose or operation.

The Canadian Environmental Protection Act would be an example of the former; the Dangerous Goods and Hazardous Wastes Management Act an example of the latter. The paragraphs which follow identify the key enactments that have relevance to the project.

10.2.1 Federal Legislative Context

Although the project is located totally on provincial lands, reference must be made to the federal environmental assessment process and to the Canadian Environmental Protection Act. Other federal legislation may provide direction to parallel provincial legislation and will be identified as necessary.

10.2.1.1 Environmental Assessment Review Process (EARP)

The federal environmental assessment review process was instigated in 1973 in part, in response to increasing public concern for the environment. In 1984 an Order in Council established the EARP Guidelines Order which has been determined by the courts to be a law of general application. Clause 6 of that Order reads as follows:-

These Guidelines shall apply to any proposal:

a) that is to be undertaken directly by an initiating department;
b) that may have an environmental effect on an area of federal responsibility;
c) for which the Government of Canada makes a financial commitment; or

d) that is located on lands, including the offshore, that are administered by the Government of Canada.

Each of the four subsections of Clause 6 stands on its own and, as long as a federal decision is required, each is a sufficient trigger of EARP. The federal assessment process may in certain circumstances involve three steps:

i) screening, a process to determine the potential environmental and directly related social effects of a proposal and the significance of those effects;
ii) initial environmental evaluation, a process to investigate in greater detail uncertainties identified by the screening; and
iii) referral for public review and the undertaking of a full environmental impact assessment.

The initiating department is responsible for i) and ii) above; an initial environmental evaluation will only be necessary if unresolved questions remain on completion of the screening. Similarly the project would be referred for public review only if there were substantive unresolved environmental problems remaining after completion of the initial environmental evaluation and/or serious public concern had been voiced.

The fact that a province may have primary responsibility in a specific set of circumstances, as it does in this instance, does not mean that a federal department or agent can defer to the province in respect to its decision making on environmental matters. Although the law does not necessarily require CBDC, a federal crown corporation, to adhere to the EARP process, it would increase their credibility in the eyes of the public to comply. Further in the context of this project, compliance would be straight forward; it would require only that step i), the initial screening process, be appropriately documented in order to demonstrate (to a court if needed) that EARP has been respected and to have information about the proposal readily available if requested by the public.

10.2.1.2 Canadian Environmental Protection Act (CEPA)

The full title of this legislation, "An Act respecting the protection of the environment and of human life and health," clearly defines its purpose. The Act seeks to provide a comprehensive framework to assist governmental control of toxic substances throughout their life cycle - from their development through to their manufacture, transport, distribution, use, storage, and, finally, their disposal as waste.

In Part V the Act addresses the topic of international air pollution and provides the authority necessary to promulgate regulations in respect to such pollution. These regulations serve two functions:

1) to indicate to the international community that Canada has met its treaty obligations; and
2) to serve as guidelines or standards to be followed by the provinces.

In fact, all Provinces have adopted standards for air emission that exceed the federal requirements; adherence to such standards will therefore ensure compliance with CEPA.

10.2.1.3 Other Federal Statutes

Several other federal statutes bear upon pollution, land use and other factors pertaining to the environment. These include the Fisheries Act, the Navigable Waters Protection Act, the Migratory Bird Act. The Canadian Wildlife Act and the Endangered Species Act. Given the location, intent, and nature of the project, however, these acts have little or no relevance to the project's implementation.

10.2.2 Provincial Legislative Context

The province not only exerts jurisdiction over the use of land within its boundaries, but ensures through legislative mechanisms that projects are developed and function in an environmentally appropriate manner. The key principles and requirements of pertinent enactments are outlined below; these enactments include:

Environmental Protection Act, R.S.N.S., 1989, c150.
Environmental Assessment Act, R.S.N.S., 1989, c149
Pipeline Act, R.S.N.S., 1989, c345
Dangerous Goods and Hazardous Wastes Management Act, R.S.N.S., 1989, c118
Private Ways Act, R.S.N.S., 1989, c358

In reviewing the legislative context, reference will be made to other acts that either have a bearing upon the development of land, or that may in some way relate to the operation of the project.

10.2.2.1 Environmental Protection Act

The purpose of the Act as stated in Section 2 is to provide for the preservation and protection of the environment. In this context, pollution is defined as

> "... a detrimental alteration or variation of the physical, chemical, biological or aesthetic properties of an environment which results or may result from an act or omission over which the Legislature has jurisdiction."

No construction or modification of a facility which may cause pollution shall commence unless plans and specifications are submitted and approved by the Minister [S. 23 (1)]. Further, if the Minister believes that a plant is discharging waste in excess of recommended standards, he may order that the emission be stopped or control equipment be installed. Of particular relevance, however, to the proposal is S. 30 (1) of the Act which states that:

> "A person responsible for an existing source of waste discharge or other pollution may submit to the Minister a program to prevent or to reduce and control the existing or additional emission or discharge into the environment of any waste from the source of the waste discharge or other pollution."

The project as defined is designed with the intent of reducing an existing emission to the atmosphere and of enhancing the current/proposed plant operations. In making its submission to the Minister as required by S. 23 (1) of this Act, the Proponent is advised to make reference to S. 30 (1).

10.2.2.2 Environmental Assessment Act

The purpose of this Act as stated in Section 2 is to:

(a) protect the environment and quality of life of the people of the Province;
(b) provide for the environmental assessment of undertakings to identify and correct or prevent, early in the planning process, potentially damaging environmental impact and thus avoid considerable costs for the adjustments or remedies which might otherwise be necessary after an undertaking has been completed;
(c) provide for public consultation respecting the potential environmental impact of an undertaking;

through the institution of environmental assessment procedures in respect to an undertaking that may be potentially damaging to the environment.

Unless specifically exempted by virtue of Section 4 (2) or (4), and this project is not so exempted, this Act applies. The Proponent shall, therefore, register the undertaking with the Minister whereupon the Minister shall determine in accordance with S. 7 whether:

(a) a preliminary report is necessary;
(b) an environmental assessment report is required; or
(c) an environmental assessment report is not required.

Should a preliminary report be necessary, the Minister shall provide the Proponent with guidelines for its preparation. In the unlikely event that a more detailed environmental assessment report would be required, more comprehensive guidelines and terms of reference would be prepared which would include plans for public consultation.

Given that the intent of the project is to reduce the emissions to the atmosphere in accordance with S. 30 (1) of the Environmental Protection Act and that the adverse impacts on the environment are either minimal or can be effectively mitigated, it is unlikely that an environmental assessment report would be required. A preliminary report as defined by this Act may be requested.

10.2.2.3 Pipeline Act

As defined in Section 3 (1) (k), a pipeline encompasses pipes and installations for the transmission of:

i) gas;
ii) oil;
iii) fluids from a well;
iv) water or effluent used or produced in connection with a well or the production or manufacture of gas or oil.

Unless exempted, no person shall construct a pipeline or any part thereof except pursuant to a permit. The exemptions as specified in Section 5 of the Act include:

> A pipeline situated wholly within property used for a refinery, absorption plant, processing plant, coal processing plant, marketing plant or manufacturing plant.

Over and above the need for a permit to conduct the pipeline in whole, or in part depending on the application of S. 5 above, a license will be required for its operation pursuant to S. 11 of the Act.

Of further relevance to the project is Section 27, which indicates that approval can be sought from either the Minister of Transportation and Communication or from the local authority, whichever is appropriate, to construct a pipeline on, across, over or under any highway or road.

10.2.2.4 Dangerous Goods and Hazardous Wastes Management Act

This Act applies to the handling of dangerous goods for any purpose and the handling of hazardous waste on property owned by the person responsible for it or elsewhere [S. 3 (1)]. Section 4 (1) requires that a person responsible for dangerous goods notify the Minister, as required by the regulations, regarding their location, approximate quantities, general purpose for which they are kept and precautions being taken for handling and storing them. Although methane is identified as a hazardous material, there does not appear to be any specific permitting requirement. The proponent however would be advised to inform the Minister of the parameters of the project.

10.2.2.5 Private Ways Act

This Act provides a means for every owner or occupier of a mine and others to acquire easements to transport products of a mine over land they do not own by presenting a petition to the Governor in Council in the form prescribed. This is detailed in Section 2; the content of a Petition must include:

(a) the nature of business which such owner or occupier is desirous of carrying on;
(b) a description of the property over which it is sought to obtain a right of way;
(c) the width of such a right of way;
(d) the nature and extent of the right required; and
(e) the amount which such owner or occupier has offered to the owner or owners of the lands sought to be crossed for a right of way across the same.

This mechanism would have some relevance if the route selected crossed private lands and no easement was forthcoming from the registered land owner.

10.2.2.6 Other Provincial Legislation

Several other provincial enactments have a bearing on the use or protection of land or upon various environmental concerns within the Province; such enactments include, but are not limited to, the following:

Wildlife Act, R.S.N.S., 1989, c504
Special Places Protection Act, R.S.N.S., 1989, c438,
Ozone Layer Protection Act, R.S.N.S., 1989
Water Act, R.S.N.S., 1989, c500
Planning Act, R.S.N.S., 1989, c346

These enactments provide the substance to specific facets of environmental law. Given the nature of the project, however, its location on lands owned, or largely owned, by the Proponents and the current predominantly industrial use of abutting lands, these enactments have little, if any, direct relevance.

10.3 RELATED MATTERS

In large measure, the safe operation of the project in an appropriate location will be ensured by adherence to the requirements of the statutes identified. Only two additional matters indirectly related to location and operation can be raised, these are:

i) issues concerning rights of way; and
ii) issues of liability in respect to nuisance.

10.3.1 Rights of Way

To fully examine the topic of rights of way as it relates to the routing of this conduit, it would be necessary to have explicit information on land ownership and on traditional usage patterns. Nevertheless, it can be stated that subject to general statutory restrictions such as those, for example, that may be imposed by land use planning legislation, the fee simple land owner, free from incumbrances, has the exclusive right to do on it anything that does not so affect other land, or its occupiers, or to cause a nuisance or injury.

Easements may impinge upon how land is used; they can be created by statute, expressly by implication, by necessity, or by prescription. As indicated in Section 9.2.2.5 above, the Private Ways Act provides a means for mine owners to acquire easements that they may need to transport the produce of their operation over land they do not own. On the other hand, local land users might be able to create an easement of necessity if the proposed conduit were to block their access to lands. The topic is a complex one and must be carefully considered in the determination of a pipeline route.

10.3.2 Liability in Respect to Nuisance

In law there is both a civil liability for nuisance and a statutory responsibility. In respect to the latter, Section 51 (1) of the Health Act, R.S.N.S., 1989, c195 states:

> No person shall put or cause to be put in any place, on land or water, any offensive matter or thing likely to endanger the public health or likely to become or cause a nuisance.

In the context of civil liability, a person whose property is physically damaged or who suffers substantial interference with the use and enjoyment of property as an indirect result of environmentally damaging actions by another party, may bring an action in private nuisance against the party responsible.

The issue of liability must be addressed, but it does not inhibit the effective implementation of the project.

10.4 ACTIONS ARISING FROM ENVIRONMENTAL LEGISLATION

There are two distinct types of action necessary to respond effectively to the requirements of the environmental legislation; these are:

i) those actions necessary to meet assessment procedures; and
ii) the approvals/permits necessary to ensure compliance with specific enactments.

10.4.1 Assessment

The primary requirement is to meet the stipulations of the provincial legislation, namely:

> to register the project with the Minister of the Environment in accordance with the Environmental Assessment Act. If a preliminary report is deemed to be necessary, the Minister shall provide the Proponent with guidelines for its preparation. Public consultation would only be required in the unlikely event that an environmental assessment report is requested.

With respect to the federal assessment context, the Proponent is recommended to:

> document the initial screening process and to have available a succinct project description to demonstrate, if necessary, compliance with the federal assessment procedures.

10.4.2 Approvals/Permits

The following approvals and permits for the project must be sought:

- approval of project plans and specifications by the Minister of Environment as required by S. 23 (1) of the Provincial Environmental Protection Act. It is recommended that in making the submission, reference to be made to S. 30 (1) of the same Act;
- permits for the construction and operation of a pipeline by virtue of the Pipeline Act; and
- approval to construct the pipeline on, across, over or under the highway/road.

10.5 CONCLUSIONS - MRA DUCT - LAND USE AND ENVIRONMENTAL ISSUES

The project will reduce the levels of methane, sulphur and nitrogen oxides emitted to the atmosphere; for this and other reasons the project should be implemented. Its implementation, nevertheless, will have to satisfy all pertinent legislative requirements. The preliminary appraisal of those requirements, presented in the preceding paragraphs, identifies no significant regulatory impediment.

Although no regulations specifically focus on the aesthetic or visual impact of the project, this issue may be raised by concerned citizens. Indeed a duct of this diameter (4.8 metres) will be very noticeable in the landscape if the proposed above ground design is pursued. To the extent possible, therefore, the routing should be kept at some distance from the public highway and in proximity to existing industrial uses. The alternative is to bury, or partially bury, the duct. This would inevitably increase costs by several million dollars and could only be considered after a detailed assessment of project viability.

11.0 PROJECT FINANCIAL ANALYSIS

11.1 BASIC ASSUMPTIONS

The reader is referred to section 3 for a listing of all project design parameters including the assumptions used to calculate the present values of all cost and revenue streams over the life of the project.

11.2 BASE CASE ANALYSIS

11.2.1 Methodology

The general approach used to analyze the costs and benefits for the single option studied was to create a computer based spread-sheet model of the cost and revenue flows over the life of the project. Present values were then calculated for each flow using the appropriate parameters referred to above. The following paragraphs briefly describe how the model was set up.

The project direct capital and construction costs are calculated from the detailed cost estimates attached in the appendices of this report. For each direct capital expenditure, indirect costs were assumed (as a percentage of direct capital costs) for the following:

-	Engineering, Procurement & Construction Management:	17%
-	Owners Costs, incl. Interest During Construction (IDC), Insurance, Customs, Taxes, etc.:	35%

These calculated amounts were then added to the direct costs to produce an estimate for the overall project capital cost. It was assumed that capital disbursements would be split evenly over the two year construction period;

thus 50% of the total project costs are assumed disbursed in year 1 with the remaining 50% disbursed in year 2.

Operating "costs" are entered into the model in appropriate engineering units, converted to dollars by the model and discounted over the life of the project. This was done to make it easier to view alternate runs of the model and identify the different "costs/ benefits" for each alternate. Thus, energy penalties associated with installing an MRA duct fan are entered as kWh; changes to coal consumption are entered in tonnes, and so on. It should be noted that all fans are assumed to be operating continuously. Thus the power consumption expressed in kW is numerically equal to the energy consumption (expressed in kWh) over a one hour operating period. The actual costs in $ / kWh (for energy) and $ / KJ (for coal) are assumed project wide constants. Operating and Maintenance costs have been calculated solely on the basis of project direct capital costs and have not been adjusted for different plant capacities.

Each of the design options studied results in reduced SO_2 emissions. The model calculates the notional benefit of this reduction by calculating the mass of SO_2 reduced each year from the net coal savings of that year. Using the life-cycle cost per tonne of SO_2 saved that was provided by NSPC, the model simply sums the total tonnage of SO_2 saved and multiplies by the life-cycle cost per tonne. No discounting is performed in this case. For information only, the model calculates the present value of net benefits, cumulative net benefits and NPV, both with and without SO_2 notional benefits included. It is recognised that there is a conceptual difficulty in summing the direct benefits of the project with "notional" benefits which are more opportunity costs in nature.

11.2.2 Options Studied

The different uses of MRA and MDM have been detailed in section 1. For ease of reference, a summary of the various design options is reproduced here:

1. Use of Mine Return Air (MRA) Alone
2. Use of Mine Drainage Methane (MDM) Alone
    - 2a. - Simple Compression
    - 2b. - Beneficiation
3. Use of MRA and MDM combined.

Options 1 and 3 both centre on the concept of providing a relatively low-pressure duct to convey the MRA (or MRA / MDM) from the mine sites to the generating station. Options 2a and 2b have as a common theme a smaller pipe conveying the compressed or beneficiated MDM from the mine sites to the generating station. As stated previously, this report deals only with the third option in detail. The other options are discussed in the study Interim Report which is reproduced in full in the Appendices.

11.2.3 Operating & Maintenance Costs

Annual O & M costs are assumed to be direct costs and to be 1.5% for static plant direct costs and 4% for rotating plant. These costs are independent of plant capacity factors. Also, for this exercise, O&M cost reductions were disregarded. The net costs are therefore approximately

0.04 x 1 million = \$ 40,000
0.015 x 22 million = \$ 330,000
for a total of \$ 370,000 per annum

11.2.4 Cost Estimates - Use of MRA Combined with MDM ($CDN, 1990)

WBS	Description	Supply	Install	Total
1	Site	100,000	400,000	500,000
21	Boilerhouse & Auxiliary Structures	1,907,000	1,907,000	3,814,000
28	MRA Duct	10,562,090	1,495,250	12,057,340
3	Boiler and Auxiliaries (incl. duct fan)	1,627,775	9,791,040	11,418,815
56	Electrical	227,675	84,510	312,185
73	Building Ventilation	121,000	96,000	217,000
Total Direct Costs		14,545,540	13,773,800	28,319,340
EPCM Costs				4,814,288
Owners Costs				9,911,769
Total Capital Costs				43,045,397

Direct costs estimates have been based on budgetary quotations received from vendors contacted during the study as well as in-house knowledge. No explicit allowance for unknowns has been added to these estimates. It has been the experience of the study team that, in general, budgetary costs such as these are consistently lower than actual costs incurred. This is not an unreasonable expectation as better information and better project definitions will be available during detailed design. For this reason, a specific contingency allowance of 15% has been added such that the total capital cost figure above represents the -15% limit. The corrected total capital cost (including contingency) is therefore $ 50.64 million. This figure is within the study terms of reference for cost estimating accuracy.

11.2.5 Present Value Analysis

Print-outs from the computer model for the project base case capital cost (i.e. $ 50.64 million) have been attached for reference. The model as implemented follows the description provided in section 11.2.1. All cost and revenue flows over the life of the project can easily be identified.

11.3 SENSITIVITY ANALYSIS

By varying the project capital costs from the minimum (-15%) to the maximum (+15%), the net present value of the project and discounted payback period will change. This exercise was done and gives the following results:

	PV Cost ($m)	PV Net Benefits ($m)	NPV	Discounted Payback (yrs)
-15%	43.04	54.61	11.57	15
0%	50.64	54.61	3.97	18
+15%	58.24	54.61	(3.63)	23

If the "notional" benefits of SO_2 abatement are included with the project net benefits, the NPV for the 0% case increases to over $ 45 million and the discounted payback period drops to 9 years. However, as has been stated above, the validity of this exercise is open to interpretation.

It should be noted that only revenue figures were varied in this manner. No specific attempt was made to vary cost data as there was no information available as to the variability of this data.

In-service Life: 20.00
Cost of Money: 10.25%
Inflation: 5.00%

cost of energy: 0.053 $/kW
cost of coal: 2.70 $/MBtu
heating value of coal : 11,695 Btu/lb
lbs per tonne : 2,204
sulphur % wht.: 3.00%

					:-	-------	-------	80%	CAP.	----
end of Service year #					1	2	3	4	5	6
end of year #		0	1	2	3	4	5	6	7	8
		1990 PV ($m)	1991	1992	1993	1994	1995	1996	1997	1998
USE OF MRA / MDM BLEND:										
INVESTMENT: **($m 1990)**		25.32	26.59	3.176	3.176	3.176	3.176	3.176	3.176	3.176
interest			2.725	2.679	2.628	2.572	2.510	2.441	2.366	[illegible]
principal			0.451	0.497	0.548	0.605	0.667	0.735	0.810	[illegible]
		25.32		27.92	3.335	3.335	3.335	3.335	3.335	3.335
interest				2.861	2.813	2.759	2.700	2.635	2.563	2.484
principal				0.474	0.522	0.576	0.635	0.700	0.772	0.851
PRESENT VALUE OF INVESTMENT:		50.64								
COSTS/BENEFITS: **($m,1990)**										A —
OPERATING AT 80% CAPACITY FACTOR:										
1 Energy increases (kWh)										
- MRA fan:	1,373	3.74			0.738	0.775	0.814	0.854	0.897	0.942
- FD/ID/PA fans:	640	1.74			0.344	0.361	0.379	0.398	0.418	0.439
2 Energy reductions (MWh/yr)										
- coal/ash handling:	(879.0)	(0.27)			(0.054)	(0.057)	(0.059)	(0.062)	(0.066)	(0.069)
3 Coal consumption (t/yr)										
- savings due to MRA	(86,789)	(35.41)			(6.992)	(7.342)	(7.709)	(8.094)	(8.499)	(8.924)
- ventilation heat saved	(10,109)	(4.12)			(0.814)	(0.855)	(0.898)	(0.943)	(0.990)	(1.039)
- extra coal to preheat	7,370	3.01			0.594	0.623	0.655	0.687	0.722	0.758

B

```
---- -------¦ ------      75%  CAP. ------- -------¦ ------ -------      65%  CAP. ------- ---------------¦
     7         8         9        10        11        12        13        14        15        16        17        18        19        20

     9        10        11        12        13        14        15        16        17        18        19        20        21        22        23

  1999      2000      2001      2002      2003      2004      2005      2006      2007      2008      2009      2010      2011      2012      2013
----------------------------------------------------------------------------------------------------------------------------------------------


3.176     3.176     3.176     3.176     3.176     3.176     3.176     3.176     3.176     3.176     3.176     3.176     3.176

2.191     2.091     1.979     1.857     1.721     1.572     1.408     1.226     1.026     0.806     0.563     0.295     (.000)
0.985     1.086     1.197     1.320     1.455     1.604     1.769     1.950     2.150     2.370     2.613     2.881     3.176

3.335     3.335     3.335     3.335     3.335     3.335     3.335     3.335     3.335     3.335     3.335     3.335     3.335     3.335

2.397     2.301     2.195     2.078     1.949     1.807     1.651     1.478     1.288     1.078     0.846     0.591     0.310      .000
0.938     1.034     1.140     1.257     1.386     1.528     1.684     1.857     2.048     2.257     2.489     2.744     3.025     3.335



-A



0.989     1.038
0.461     0.484


0.072)   (0.076)


9.370)   (9.839)

1.091)   (1.146)
0.796     0.035
```

B

MRA

D —

OPERATING AT 75% CAPACITY FACTOR:								
1 Energy increases (kWh)								
- MRA fan:	1,287	1.59						
- FD/ID/PA fans:	600	0.74						
2 Energy reductions (MWh/yr)								
- coal/ash handling:	(863.0)	(0.12)						
3 Coal consumption (t/yr)								
- savings due to MRA	(84,310)	(15.60)						
- ventilation heat saved	(9,477)	(1.75)						
- extra coal to preheat MRA	7,047	1.30						
OPERATING AT 65% CAPACITY FACTOR:								
1 Energy increases (kWh)								
- MRA fan:	1,116	1.44						
- FD/ID/PA fans:	520	0.67						
2 Energy reductions (kWh)								
- coal/ash handling:	(822)	(0.12)						
3 Coal consumption (t/yr)								
- reduction due to MRA	(78,767)	(15.26)						
- ventilation heat saved	(8,214)	(1.59)						
- extra coal to preheat MRA	6,294	1.22						
OPERATING & MAINTENANCE ($)								
- net increases:	370,000	4.18	0.428	0.450	0.472	0.496	0.521	0.547
		-----	-----	-----	-----	-----	-----	-----
PRESENT VALUE OF TOTAL NET BENEFITS:								
- without SO2 notional benefits:		(54.61)	(5.76)	(6.04)	(6.35)	(6.66)	(7.00)	(7.[illegible])
- with SO2 notional benefits:		(95.77)						

E

c

- D

```
     1.022   1.073   1.127   1.183   1.242
     0.476   0.500   0.525   0.552   0.579

    (0.078) (0.082) (0.086) (0.091) (0.095)

   (10.035)(10.537)(11.064)(11.617)(12.198)

    (1.128) (1.184) (1.244) (1.306) (1.371)
     0.839   0.881   0.925   0.971   1.020



                                                                1.131   1.188   1.247   1.309   1.375   1.444   1.516
                                                                0.527   0.553   0.581   0.610   0.641   0.673   0.706

                                                               (0.095) (0.100) (0.105) (0.110) (0.116) (0.121) (0.127)

                                                              (11.966)(12.564)(13.193)(13.852)(14.545)(15.272)(16.036)

                                                               (1.248) (1.310) (1.376) (1.445) (1.517) (1.593) (1.672)
                                                                0.956   1.004   1.054   1.107   1.162   1.220   1.281


.574    0.603   0.633   0.664   0.698   0.733   0.769   0.808   0.848   0.890   0.935   0.982   1.031   1.082
-----   -----   -----   -----   -----   -----   -----   -----   -----   -----   -----   -----   -----   -----

7.71)   (8.10)  (8.27)  (8.69)  (9.12)  (9.58) (10.05)  (9.89) (10.38) (10.90) (11.45) (12.02) (12.62) (13.25)
```

F

```
CUMULATIVE NET BENEFITS (Discounted)

   - without SO2 notional benefits:                                  (4.30)  (8.39) (12.28) (15.99) (19.53) (22.89)
   - with SO2 notional benefits:                                     (6.44) (12.68) (18.73) (24.59) (30.27) (35.79)

NET PRESENT VALUE:

   - without SO2 notional benefits:         ($3.97) million
   - with SO2 notional benefits:           ($45.12) million
                                           ========
SO2 avoided (tonnes/yr):                                            (5,372) (5,372) (5,372) (5,372) (5,372) (5,372)
total SO2 avoided over
             20 years:  (102,884)          ($41.15) million
                                                    (notional value)
```

```
6.10) (29.15) (31.98) (34.67) (37.24) (39.68) (42.01) (44.08) (46.06) (47.94) (49.73) (51.44) (53.06) (54.61)
1.14) (46.34) (51.25) (56.02) (60.67) (65.20) (69.60) (73.62) (77.53) (81.35) (85.08) (88.72) (92.28) (95.77)



,372) (5,372) (5,204) (5,204) (5,204) (5,204) (5,204) (4,841) (4,841) (4,841) (4,841) (4,841) (4,841) (4,841)
```

Volume

2

FENCO SHAWINIGAN ENGINEERING (1985) LIMITED

A DIVISION OF Lavalin

TECHNICAL/ECONOMIC STUDY OF THE FEASIBILITY OF SUPPLYING AND UTILIZING LINGAN / PHALEN MINE METHANE AT LINGAN GENERATING STATION

[Part of the Program of the Federal Panel on Energy R&D (PERD)]

FINAL REPORT

Volume 2 of 2

Prepared by:

Fenco Shawinigan Engineering (1985) Limited
Suite 200, Park Lane Terraces
5657 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

Our Reference # 58613

Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada.

SSC File No.: 06SQ.2344-0-9033

Contract File No.: 23440-0-9033/01-SQ

CANMET Scientific Authority: Dr. F.D.S. Preto

Date: March, 1991

236 pp

MICROMEDIA

APPENDIX 1

REFERENCES

1. Report "Utilization of Mine Return Air - Lingan Harbour Mine" for Cape Breton Development Corporation - May 1983,

2. Report "Methane Fuel - Power Generation Study" for Cape Breton Development Corporation - September 1988,

3. Letter 1990, 04, 25 - Cape Breton Development Corporation (John C. Campbell, P.Eng.) to Dr. David Granatstein, P.Eng., Chairman - Technical Steering Committee - Mine Methane Utilization Project,

4. Letter 1990, 06, 26 - Nova Scotia Power Corporation (David L. Granatstein, Ph.D., P.Eng.) to Brian King, Fenco Shawinigan, Re: Mine Methane Project, Levelized Value for SO_2 Removal,

5. CANMET - MRA and Reburn Testing: Preliminary Summary presented by Dr. Fernando Preto at a Study Progress Meeting July 6, 1990,

6. Memorandum - Des Cousens - Special Studies Head, NSPC to Brian King, Fenco Shawinigan - Dated 1990, 07, 11 Re: NO_x Emissions Levels - Lingan Generating Station,

7. Telecon - NSPC - Richard Penny to Brian King, Fenco Shawinigan, July 1990. Power to drive the fan on NSPC Lingan Generating Station Site will be costed at 5.3¢/kWh. This is the value attributed to other Lingan "Station Transformer" loads.

8. Chen, et al., Optimization of Reburning for Advanced NO_X Control on Coal-fired Boilers, JAPCA, 39(10), 1375 - 1379 (October, 1989).

9. Correspondence dated November 13th, 1990 from FSEL to Dr. David Granatstein, Chairman, Technical Steering Committee.

10. Correspondence dated December 10, 1990 from Dr. Paul Amyotte and Dr. Mike Pegg of the Department of Chemical Engineering, Technical University of Nova Scotia.

11. Ramathan, V., Cicerone, R.J., Singh, H.B. and Kiehl, J.T., Journal of Geophysical Research, 90 (D3), 5547-5566 (1985). "Trace Gas Trends and their Potential Role in Climate Change".

12. Abrahamson, D., "Relative Greenhouse Effect of Fossil Fuels and the Critical Contribution of Methane", presented to the Oil Heat Task Force, June 15th, 1989.

APPENDIX 2

CORRESPONDENCE WITH VENDORS
AND
SUB-CONSULTANT REPORTS

APPENDIX 2.1
MRA DUCT FAN

October 30, 1990

Attention:

Dear Sirs:

RE: Lingan/Phalen Mine Methane Study

Fenco Shawinigan Engineering (1985) Limited (FSEL) has been commissioned to undertake a study to determine the most attractive way of utilizing methane emanating from Cape Breton Development Corporation coal mining operations at Lingan and Phalen mines. The Executive Summary of Interim Report of this study together with the schematic of the proposed concept is attached. The study has now proceeded to Phase 2 where the feasibility of the selected option is being studied and preliminary design is proceeding.

You are invited to provide a budget quotation for the MRA Fan and driver (Titled Power Station Suction Fan on the Schematic) as described on the attached outline Specification. You are requested to provide the operating data listed for your proposed equipment. At this time the project design concept will attempt to cater to a range of equipment and in this regard your response is requested by November 9, 1990. If the project proceeds to detailed design, suppliers will be asked to submit firm quotations and precise operating data for the proposed equipment. The operating data is preliminary and will be revised in detailed design.

If you have any questions please do not hesitate to contact the undersigned.

Yours very truly,

FENCO SHAWINIGAN ENGINEERING (1985) LIMITED

P.J. Mahon, P.Eng.
Project Engineer

PJM/cg
58613P01L
Encl.

Sent to:

Canadian Blower & Forge
Suite 402, 1220 Shephard Avenue East
Willowdale, Ontario
M2K 2S5
Attention: Mr. J. Ogryzlo

Howden Sirocco Canada
1510 Birchmount Road
Scarborough, Ontario
M1P 2G6
Attention: Mr. Max Bacon

Sheldons Engineering Limited
1185 Franklin Boulevard, Unit 8
Cambridge, Ontario
N1R 2Y5
Attention: Mr. Tom Davison

Novenco Canada Inc.
400 - 303 Moodie Drive
Nepeau, Ontario
K2H 9R4
Attention: Mr. Ralph Warring, P.Eng.

Lingan/Phalen Mine Methane Study

MRA Fan Outline Specification
Fenco Shawinigan Engineering (1985) Limited
Project #58613
October 30, 1990

Project Description:	See Executive Summary of Interim Report and Schematic attached. (Project Cost Data deleted)
Fan Type:	Centrifugal
Medium to be Handled:	Mine Return Air (MRA), air with a Methane content of 0.4%-0.6% Methane.
Mode of Operation:	The Fan will be controlled by means of variable inlet valves (VIV) or variable speed to produce a fixed discharge pressure. The discharge dampers allowing MRA into the power station forced draft fans inlet ducts will individually react to the forced draft fans demands' and the resultant variations in the pressure in the MRA fan discharge pressure will initiate a control signal. This control signed will vary VIV setting or speed setting to restore the MRA fan discharge pressure to its set point.
MRA Fan Location:	Nova Scotia Power Corporation Lingan Generation Station, Lingan Cape Breton, Nova Scotia

Duty:

The fan will perform at all flowrates between $209m^3/s$ and $380m^3/s$. The specific points listed below are for fan and control system efficiency evaluation.

Operating Point No.	Flow Rate		Static Head Fan Discharge		Static Head Fan Suction		% of Time
	M^3/s	ft^3/mm	in H_20	Pascal	in H_20	Pascal	
1	380	805,000	3.5	870	-9.51	-2370	20
2.	335	710,000	3.5	870	-8.40	-2090	46
3.	293	621,000	3.5	870	-7.30	-1820	16
4.	251	532,000	3.5	870	-6.20	-1540	11
5.	209	443,000	3.5	870	-5.40	-1340	7

MRA Fan Outline Specification

Fan Arrangement:

Preliminary layout for the feasibility study is based on double width double inlet design, arrangement No.3 with the fan rotor supported at both ends. Discharge will be upblast. Vendor may propose an alternate in addition to this.

Fan Driver:

Direct drive between motor and fan is preferred. (ie. no gear reducer)

Equipment Included:

Four separate budget prices are requested for the equipment, listed as Package A,B,C and D. Package D reflects the necessity to match fan and motor characteristics such as inertia and to match the motor with its drive system. However equipment procurement policies or Vendors ability to supply requires that pricing of discrete components be supplied.

Equipment Included Package A:

- Fan
- Inlet box connecting fan to single inlet duct flange.
- Bearings, bearing cooling, bearing pedestals as required.
- Mechanical couplings and guards for drive train.
- Brake, manually and electrically operated.
- Fan shop painted with epoxy primer.
- Flanged outlet.

Equipment Included Package B:

- Variable inlet vanes.

Equipment Included Package C:

- Electric induction motor. Power supply is 4160V/3/60.
- Motor baseplate.

Equipment Included Package D:

- All equipment list in packages A & C above without Package B (VIV)
- Variable speed drive. A complete variable frequency drive system for the electric motor is required. Units produced by ASEA or GEC Canada or equal are being considered.

Equipment not Included:

- Control and instrumentation outside of the variable speed drive.
- Ductwork beyond single inlet and outlet flanges.
- Installation and commissioning costs (may be quoted as separate additional item if bidder wishes.)

MRA Fan Outline Specification

Data Required

.1 Budget quotation price
Package A
Package B
Package C
Package D

.2 Fan description, materials of construction and general arrangement.

.3 Fan performance curve.

.4 Operating data. (see notes below)

	Variable Inlet Vanes			Variable Speed		
Operating Point No.	Fan kW	Motor kW	RPM (Fixed)	Fan kW	Drive Input kW	RPM
.1						
.2						
.3						
.4						
.5						

.5 Full load current at 380m^3/s.

.6 Starting current.

.7 Starting time.

Notes: (1) For variable speed units the drive input kW means total electrical power to the terminals of the drive unit. (2) In the event that a budget quotation is not supplied for variable speed, the fan kW at speeds corresponding to the operating points listed are still requested on the basis that the fan may be run at variable speed by equipment supplied by others.

RECEIVED
NOV - 8 1990

NOVENCO

NOVENCO

G. Ralph Warring P. Eng.
Eastern Regional Manager

NOVENCO Canada Inc.
400-303 Moodie Drive
Nepean, Ontario K2H 9R4
Telephone (613) 596-9447
Telefax (613) 596-3344

NOVEMBER 07, 1990

FENCO SHAWINIGAN ENGINEERING
200 Park Lane Terraces
5657 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

Attention: Mr. P. J. Mahon P.Eng.
Project Engineer

Project : Lingan/Phalen Mine
Location : Cape Breton
R. F. Q. : 58613
Quote No : OTT-683

Gentlemen:

We are pleased to submit this budget proposal on the M R A Fan for this project.

Prices are F.A C. our Cambridge, Ontario plant in Canadian Funds all freight, duty and taxes extra and are todays prices valid for 30 days for shipment by November 1991, after which date escallation would apply in accordance with Statistics Canada indices as noted on the form EC 8306 attached.

Terms and conditions would be in accordance with Form GPI-2M-8-88 also attached.

Approval drawings would be furnished in 6/8 weeks after receipt of an order. Shipment would be 24/30 weeks after approval of drawings and release to manufacture.

Yours very truly,

G. Ralph Warring

G. Ralph Warring P.Eng.
Eastern Regional Manager
NOVENCO CANADA INC.

GRW/wp

NOVENCO

CLIENT : FENCO SHAWINIGAN ENG'G
FILE NO : 58613
DUTY : M R A FAN

PROJECT :LINGAN/PHALEN
QUOTE NO :OTT-683
DATE :90-11-07

PACKAGE "A"

FAN SIZE	3000	TYPE	CSDC	SERIES	3260	CENTRIFUGAL	AIRFOIL
WIDTH	DWDI	ARR	3 D	CLASS	4	QUANTITY	ONE

PRICE(each)..	$275,904.00 ✓

EXTRAS

- Falk # 1160T10 flexible coupling with guard......	4,970.00 ✓
- Forced Oil Lubrication System for Dodge bearings in lieu of water cooling, complete with standard features plus dual filters, air to oil cooler, tank heater and electrical control panel..........	17,080.00 ✓
- Epoxy prime coat finish	INCL.
- Manual holding break..............................	1,900.00 ✓
TOTAL PRICE PACKAGE "A" with above accessories.....	299,854.00 ✓

SPARES (when ordered with fan)

- fan bearings, complete	(2)	19,913.00
- fan bearing liners only	(2)	10,952.00
- shaft seals	(2)	1,788.00

PACKAGE "B"

Conoidal type variable inlet vane damper , less actuator

PRICE..	$52,136.00 ✓

SPARES (when ordered with fan)

- spare set of damper bearings......................	7,974.00 ✓

NOVENCO

CLIENT : FENCO SHAWINIGAN ENG'G
FILE NO ; 58613
DUTY : M R A FAN - OPTION 3

PROJECT : LINGAN/PHALEN
QUOTE NO : OTT-683
DATE : 90-11-09

PACKAGE "E"

FAN SIZE 3600/1800 TYPE ASN VARIAX VARIABLE PITCH IN MOTION
AXIAL FLOW FAN ARR 3 D SINGLE STAGE QUANTITY ONE

PRICE (each)	$602,926.00

EXTRAS

- Special tools	$ 17,325.00
TOTAL PRICE PACKAGE "E" with above accessories	$650,398.00

SPARES (when ordered with fan)

- fan bearings, complete	(2)	$ 18,845.00
- one set of fan blades	(30)	47,540.00
- rotating oil seal	(1)	6,955.00

PACKAGE "F"

- One 2250 HP 60/3/4160v/720 RPM motor TEAAC enclosure with bearing RTD'S, space heater and soleplate.

PRICE	$201,200.00

PACKAGE "C"

One 2250 HP 60/3/4160v/600 RPM motor with TEAAC enclosure bearing RTD'S, space heater and soleplate.

PRICE	$308,750.00

PACKAGE "D"

PACKAGE "A" PRICE	$299,854.00
PACKAGE "C" PRICE	308,750.00
VARIABLE SPEED DRIVE 6 pulse, liquid cooled I.M. drive 2250HP 60/3/4160v with dry type isolation transformer (G E CANADA)	632,500.00
PACKAGE "D" TOTAL PRICE	$1,241,104.00

SIGN BRIEF

PAGE 31 of

PROJECT Lingan Methane Study

Department 964 Project No 58613 Act A3 Sub 1 62 Sub 2 10 Sub 3 00

ETAILS Fan Capital Costs Summary

REPARED BY (rint) P.J. Mahon (initials) PJM DIVISION FSEL Mech. DATE Y 91 M 01 D 4

ERIFIED BY (print) (initials) DIVISION DATE Y M D

CAPITAL COSTS FOR FANS

	A	B	C	D	E	F
	Novenco Variable Inlet Vanes Centrifugal Fan	Howden Variable Inlet Vanes Centrifugal Fan	CDN. Blower Variable Inlet Vanes Centrifugal Fan	Novenko Var. Pitch In Motion Axial Fan	Novenco Electrical Var Speed Centrifugal Fan	Novenco Fluid Coupling Centrifugal Fan
Fan	276,000	180,000	302,000	603,000	300,000	276,000
Lube Cooling	17,000	17,000 E	—	—	Included	N.A.
Brake	2,000	2,000 E	2,000 E	2,000 E	Included	2,000
Inlet Box	Included	30,000 E	Included	N.A.	Included	Included
Variable Inlet Vanes	52,000	23,000	66,000	N.A.	N.A.	N.A.
Motor	309,000	309,000	309,000	201,000	309,000	309,000
Fluid Coupling	N.A.	N.A	N.A.	N.A	N.A.	509,000
Elect. Variable Speed Drive	N.A.	N.A.	N.A.	N.A	633,000	N.A.
Shaft Coupling	5,000	Included	Included	Included	Included	Included
	661,000	561,000	679,000	806,000	1,242,000	1,096,000

.1 Costs In Column A Carried For This Study

.2 Costs In Columns B–F Are For Comparison And Would Require Review Before Being Used As Base Costs For Alternate Selections

.3 Costs In Columns D, E & F Do Not Include Additional Infrastructure Which Could Be Required E.G. Motor Control Centre Changes For "E", Foundation Changes For "F" Etc. Costs Should Not Be Interpreted As Valid For Future Vendor Selection

APPENDIX 2.2
MRA TRANSMISSION DUCT

armtec
A Division of Jannock Steel Fabricating Company

23 November, 1990

Fenco Shawinigan Engineering (1985) Ltd.
Suite 200, Park Lane Terraces
5657 Spring Garden Road,
Halifax, N.S.
B3J 3R4

Attention: Peter M. Adams, P.Eng.
Senior Civil Engineer

Re: Mine Methane Utilization Study

Dear Sir:

Please find enclosed our final recommendations for this study. Following our meeting in September, our engineering department has spent significant time in determining a viable corrugated steel answer to this problem.

As you pointed out, Hel-Cor pipe has several distinct advantages over Multi-Plate in this application, fewer joints leading to fewer sealing problems and significantly less assembly time. In most cases the cost of freight would offset the assembly savings, however, as the proposal here is to set up a mill on site, the savings in assembly cost will be fully realized.

Multi-Plate, on the other hand, also has distinct advantages, significantly higher strength of section and no loss of strength at couplings.

As we have discussed, the initial uncertainties in regards to the diameter of the duct, varying from 3600mm to 4800 have been difficult from a design viewpoint. Also, conventional 125mm X 25mm corrugation CSP is at its design threshold at diameters greater than 3000mm. Above this diameter, the Multi-Plate corrugation (152mm X 51mm) is usually recommended for strength and economy.

The size of the project, allows us to consider another option - a CSP profile between 125 X 25 and Multi-Plate. After significant review in our engineering and manufacturing departments, as well as several meetings with a tooling manufacturer, we have finalized on a hard metric corrugation - 150mm X 40mm, a complete section property table is attached.

Suite #110, 3 Spectacle Lake Drive, Dartmouth, Nova Scotia B3B 1W8 • Telephone: (902) 468-2027 Fax: (902) 468-7781

This deeper corrugation has a significantly higher moment of inertia (I), gauge for gauge, than 125mm X 25mm. The increased moment of inertia leads directly to increased pipe stiffness allowing flexibility requirements to be met with only 2.8mm wall thickness. Standard 125 X 25 corrugation in these sizes does not meet flexibility requirements even with 4.2mm wall thickness.

I am recommending that only externally stiffened spans be considered. Angles welded on the outside, top and bottom, will add moment resistance, as well as significantly reduce deflections. Continuous angles will also rule out coupler pull-out. We propose that the pipe length be increased to 15 M, and that all couplings be over supports. Supports then will be at 15 M, centre to centre. A 600mm wide half-cradle similar to the one attached , would be required at each support. A modified version (deeper corrugation) of our H-500 full width double strap hugger band coupler is recommended.

Based on the following design conditions:

- self weight (mass) of pipe: 337 KG/M 4000mm dia.
  403 KG/M 4800mm dia.

- wind load - N.B.C. Sydney N.S.

- ice accumulation 50mm thick

- live load 2.2 KN/M

At a maximum span of 15 M, the 4000mm dia. pipe will require 75mm X 75mm X 6mm continuous angles welded top and bottom, while the 4800mm diameter pipe would require 75mm X 75mm X 8mm angles.

While I'm sure this alternative will lead to the most economical solution, there will be an extended lead time required to manufacture the tooling, as well as set-up and test the mill. I would think at least 4-5 months would be a realistic time frame.

As for thermal expansion, I would recommend the installation of thermal expansion joints at all elbows, and especially at the point where the pipe runs alongside the power plant.

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To reduce the frictional losses in the pipe, I recommend a light gauge steel liner which may be spot welded in place at the time of fabrication.

As you can see, I am basing my recommendations on 15 M lengths of pipe and spacings between supports of 15 M. These are the optimum spacings and I do not recommend an unsupported pipe.

Also enclosed, is the derivation of the maximum span formula used in making our calculations. If desired, a complete set of calculations can be made available to you.

Please do not hesitate to contact me for any reason.

Yours very truly,

ARMTEC CONSTRUCTION PRODUCTS

R Power.

R.J. Power, P.Eng.
Sales Engineer

Suite #110, 3 Spectacle Lake Drive, Dartmouth, Nova Scotia B3B 1W8 • Telephone: (902) 468-2027 Fax: (902) 468-7781

$$f' = \frac{\left(\frac{1}{2} f b d\right)\left(\frac{1}{2}\frac{y}{t}\right)}{3 \times \frac{1}{12} t^{3}} \pm \frac{f\frac{y}{t}}{\frac{y}{t}}$$

$$f' = \frac{3fd}{t} \pm f$$

$$f' = f\left(\frac{3d}{t} \pm 1\right)$$

$$f' = \frac{\omega l^{2}}{8\pi R^{2} t}\left(\frac{3d}{t} \pm 1\right)$$

MAXIMUM SPAN $= R\sqrt{\dfrac{8\pi f_{allow}\, t}{\omega\left(\frac{3d}{t} \pm 1\right)}}$

NOTE: The ultimate extreme fibre stress found by applying test data on CSP to the above formula was found to be 120,000 psi (827.376 MPa). Previous work has suggested ~~that~~ the use of 30,000 psi (206.844 MPa) as an allowable working stress for Multi-Plate.

p4 OF EXAMPLE OF 108 PI MR

IF FOS = 2.5 AS RECOMMENDED IN ATKINS·HATCH REPORT

$f_y = 230$ MPa

$f_{allow} = 92$ MPa

Then, use $\frac{2}{3}$ of the resulting maximum span.

p1 OF JULY 1966 EXAMPLE.

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DESCRIPTION ____
BY ____ CK'D. ____
JOB NO. ____
DATE ____
SHEET ____ OF ____

NOTES FROM JUNE 1958

IF THE PIPE WERE A PLAIN-WALLED PIPE, THE EXTREME FIBRE STRESS (f) WOULD BE OBTAINED BY THE FORMULA USED FOR BEAMS:

$f = \frac{M}{S}$ WHERE

f = STRESS
M = MOMENT
S = SECTION MODULUS = $\frac{I}{y}$
I = MOMENT OF INERTIA
y = DISTANCE FROM NEUTRAL AXIS TO THE EXTREME FIBRE

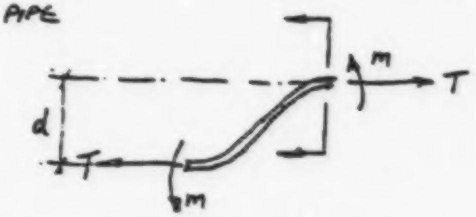
FOR A SIMPLY SUPPORTED BEAM $M = \frac{w\ell^2}{8}$

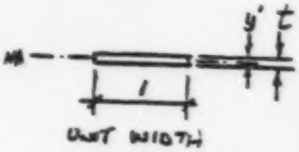
WHERE w = UNIFORMLY DISTRIBUTED LOAD
ℓ = SPAN

FOR A THIN-WALLED PIPE $I = \pi R^3 t$

FOR A CIRCULAR PIPE $y = R$ $\therefore \boxed{f = \frac{w\ell^2}{8\pi R^2 t}}$

FOR A CORRUGATED PIPE





$T = f(1)(t) = ft$

$A = (1)(t) = t$

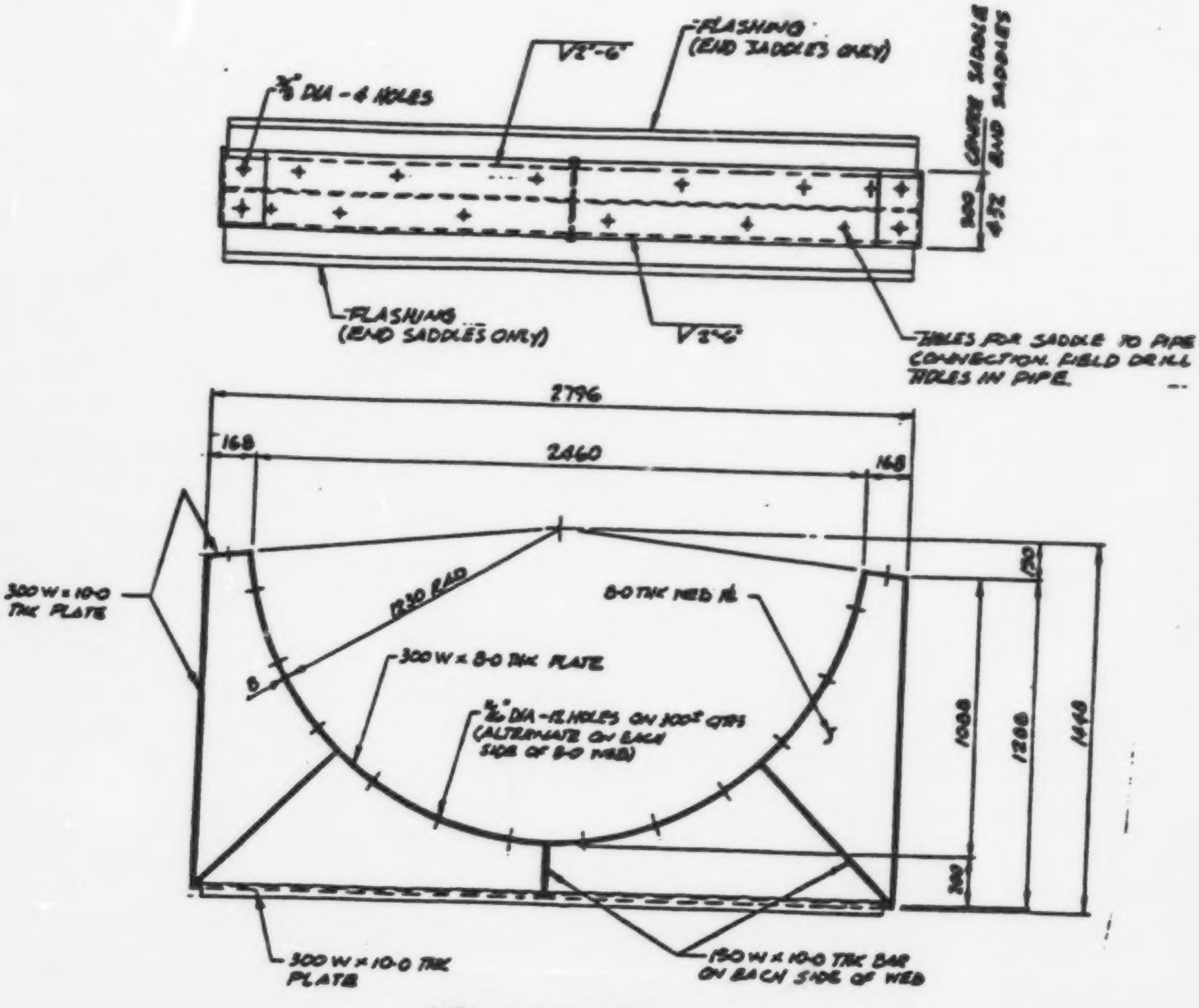
$\boxed{f' = \frac{my'}{I'} \pm \frac{I}{A}}$

$m = \frac{Td}{2} = \frac{1}{2}ftd$

$y' = \frac{1}{2}t$

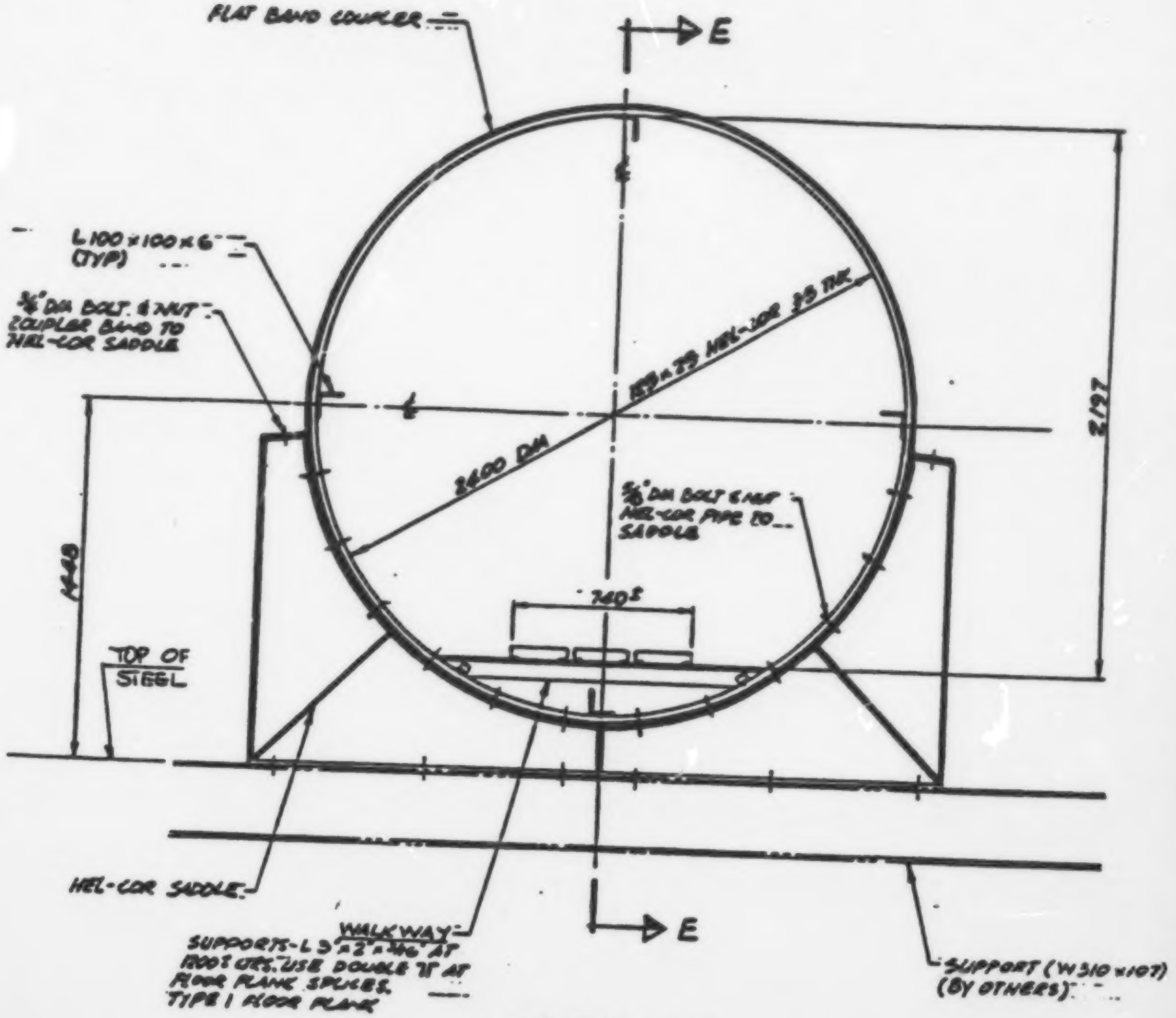
$I' = \frac{1}{12}(1)(t)^3 = \frac{1}{12}t^3$

NOTICE: THE DESIGN, DATA AND
[illegible]ATION [illegible] TING [illegible] TO [illegible] OR
NOT TO BE USED, DISSEMINATED, OR
REPRODUCED IN WHOLE OR PART WITHOUT
THE WRITTEN CONSENT OF ARMTEC.


3/8" DIA - 4 HOLES
V 3'-6"
FLASHING (END SADDLES ONLY)
CENTER SADDLE
END SADDLES
300
432
FLASHING (END SADDLES ONLY)
V 3'-6"
HOLES FOR SADDLE TO PIPE CONNECTION. FIELD DRILL HOLES IN PIPE.
2796
168
2460
168
300 W x 10.0 THK PLATE
1230 RAD
8
8.0 THK WEB PL
300 W x 8.0 THK PLATE
13/16" DIA - 12 HOLES ON 300± CTRS (ALTERNATE ON EACH SIDE OF 8.0 WEB)
130
1088
1200
1448
300
300 W x 10.0 THK PLATE
150 W x 10.0 THK BAR ON EACH SIDE OF WEB

HEL-COR SADDLE

DATE
SCALE
DRAWN
CHECKED
REVISED
APPROVED
DRAWING NO.
REV.

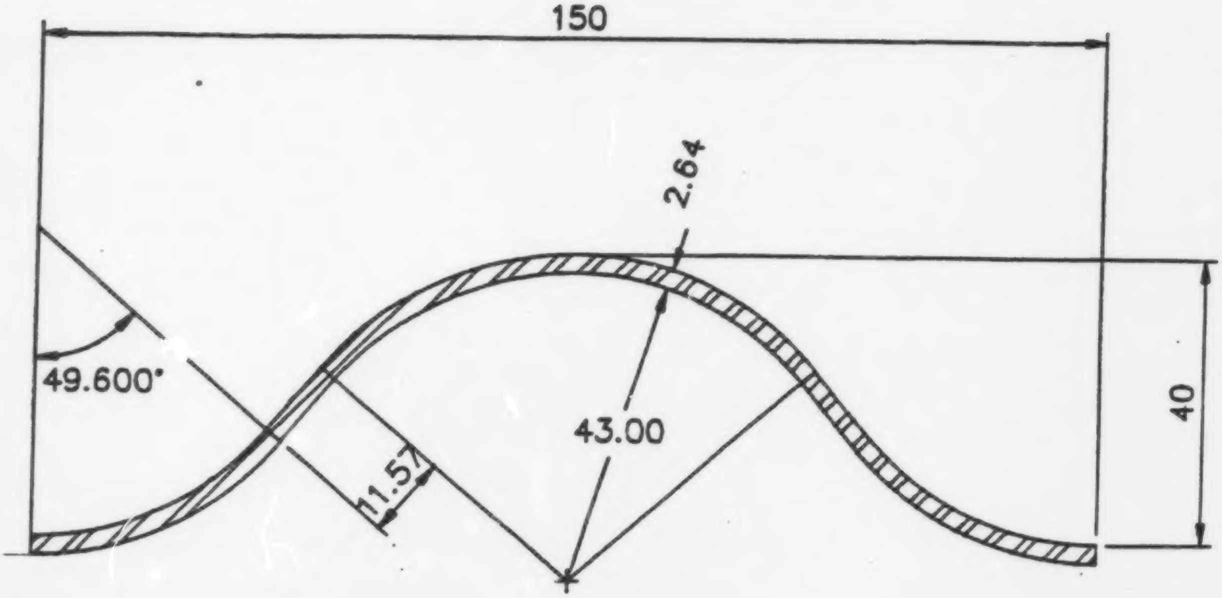

FLAT BAND COUPLER
E
L100×100×6 (TYP)
5/8" DIA BOLT & NUT COUPLER BAND TO HEL-COR SADDLE
℄
153×25 HEL-COR 3.5 THK.
2400 DIA
2197
1448
5/8" DIA BOLT & NUT HEL-COR PIPE TO SADDLE
740
TOP OF STEEL
HEL-COR SADDLE
WALKWAY
SUPPORTS-L 3"×3"×1/4" AT 1200± CTRS. USE DOUBLE "T" AT FLOOR PLANK SPLICES. TYPE 1 FLOOR PLANK
E
SUPPORT (W310×107) (BY OTHERS)

SECTION B-B

THIS IS A PROPRIETARY [illegible] OF ARMTEC. THE [illegible] DESIGN, DATA AND INFORMATION RELATING THERETO IS NOT TO BE USED, DISSEMINATED, OR REPRODUCED IN WHOLE OR PART WITHOUT THE WRITTEN CONSENT OF ARMTEC.

armtec

DATE	SCALE
DRAWN	CHECKED
REVISED	APPROVED
DRAWING NO.	



SECTION – 150 x 40 mm CORRUGATION PROFILE

SECTIONAL DESIGN PROPERTIES FOR CORRUGATED CSP SHEET

CORRUGATION PROFILE : 150 x 40 mm
CORRUGATION RADIUS (CR) : 43.00 mm

1	2	3	4	5	6	7	8	9
WALL THICKNESS		AREA	TANGENT LENGTH	TANGENT ANGLE	MOMENT INERTIA	SECTION MODULUS	RADIUS GYRATION	DEVELOPED WIDTH FACTOR
SPECIFIED	DESIGN							
	T	A	TL	Δ	I	S	r	WF
mm		mm^2/mm	mm	DEGREES	mm^4/mm	mm^3/mm	mm	*
1.6	1.40	1.646	16.264	47.600	338.90	16.37	14.349	1.176
2.0	1.82	2.141	14.121	48.344	441.57	21.12	14.362	1.176
2.8	2.64	3.108	11.567	49.600	643.34	30.18	14.387	1.177
3.5	3.35	3.948	8.775	51.046	819.47	37.81	14.408	1.178
4.2	4.08	4.813	4.313	53.527	1001.88	45.46	14.428	1.180

* WF MEASURES FLAT SHEET WIDTH TO PRODUCE CORRUGATED WIDTH. PROFILE SECTION PROPERTIES CALCULATED FROM DESIGN THICKNESS.

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A Division of Jannock Steel Fabricating Company

28 November, 1990

Fenco Shawinigan Engineering (1985) Ltd.
Suite 200, Park Lane Terraces
5657 Spring Garden Road,
Halifax, N.S.
B3J 3R4

Attention: Peter M. Adams, P.Eng.
Senior Civil Engineer

Re: Quotation for CSP Methane Duct

Dear Sir:

Following our meeting of November 23, 1990, we have tabulated all our costs associated with this project and are enclosing them herewith. These costs are based on current 1990 prices, and one can assume an inflation factor of 5% to estimate the future cost. In any event, we would hold to the prices quoted for all of 1991.

As a result of fabricating the corrugated steel pipe on site and then lining it with 24 gage, galvanized sheeting, we anticipate a direct benefit to the local community in the form of 15 to 20 jobs for welders, sheet metal workers, and labourers.

We anticipate a production rate, on site, of 45M of fully lined, CSP duct per 8 hour shift. Based on a 60 hour work week, the fabrication would be complete in approximately 2 months. We would prefer the fabrication period to be during the summer months. This minimizes the shelter required. We will require a covered concrete slab, approximately 30 ft. X 40 ft, in order to properly set up the CSP rolling mill.

The greatest amount of time that we will require, will be from the time an award of contract is made until the time we are ready to mobilize on site. We anticipate that to acquire the tooling, set it up in house and completely test the system will take 4 to 5 months. We feel that the in-house testing phase is key to our overall success with this project.

Suite #110, 3 Spectacle Lake Drive, Dartmouth, Nova Scotia B3B 1W8 • Telephone: (902) 468-2027 Fax: (902) 468-7781

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After mobilization on site we would have all our equipment ready to commence fabrication within one month, and as previously stated, we could complete the fabrication within 2 months.

Therefore, from the time of award until completion of fabrication, we estimate a period of 7 to 8 months. We also feel that these time estimates are completely realistic and do take into account any unforseen delays.

Please review the attached quotation, and please do not hesitate to contact our office if you have any questions.

Yours Very Truly,
ARMTEC CONSTRUCTION PRODUCTS

Bob Power.

R.J. Power, P.Eng.
Sales Engineer

enclosures incl.

Armtec
Construction Products

ATLANTIC REGION OFFICE
[illegible]

QUOTATION

TO: Fenco Shawinigan Engineering (1985) Ltd.
5657 Spring Garden Road
Halifax, N.S.

DATE: Nov. 30, 1990

QUOTE NO.:

F.O.B. Sydney, N.S.

TERMS: Net 30 Days on approved credit

SHIPMENT: As required

PROJECT: CSP Methane Duct

Gentlemen:
We are pleased to submit our quotation for the SUPPLY ONLY of the undernoted Drainage & Allied Products.

Quantity	Thickness	Size	Description	Price	Per	Amount
1140M	2.8mm	4000mm	150X40mm CSP duct c/w 24 gage lining	1400-	M	1,596,000-
1410M	2.8mm	4800mm	150X40mm CSP duct c/w 24 gage lining	1600-	M	2,256,000-
10M	3.0mm	4000mm	Multi Plate (assembled) c/w explosion doors	2000-	M	20,000-
175	H-500	couplers	c/w O-rings & gasket	1000-	ea	175,000-
1	2.8mm	4000mm	WYE	10,000-	ea	10,000-
1	2.8mm	4800-4000mm	reducers	10,000-	ea	10,000-

Total Price Quoted $4,067,000-

This quotation is firm for acceptance within thirty (30) days from this date and is subject to the conditions overleaf

Federal Sales Tax is: Extra ☒ Included ☐
Provincial Sales Tax is: Extra ☒ Included ☐

Armtec Inc.

Bob Power.

F&A Inc.

Foundations & Anchors, Inc.
620 Vanadium Road
Bridgeville, PA 15017
412/257-8889 • Fax-257-3327

October 29, 1990

NOV 6 1990

Peter Adams, P.E.
LAVALIN,INC.
Suite 200, Park Lane Terraces
5657 spring Garden Road
Halifax, Nova Scotia B3J 3R4
CANADA

Dear Peter,

I have enclosed a copy of our brochure, sample calculations and information on capacities in response to your telephone call of October 29, 1990.

The anchoring and foundation systems are particularly adaptable to engineering and construction requirements. The systems are portable, neither labor nor equipment intensive and simple to use.

The anchors are used to resist axial loads from 5 Tons to 150 Tons for a variety of applications. Typically the anchors are used for guy leads for utility or communication towers or poles, tie-backs for retaining structures, and securing underground storage tanks. Additionally, the anchor is used as a removable and reusable tool to install foundations.

The foundations have all the advantages of both a friction pile and a spread footer. The bearing and uplift capabilities are read directly from the gauge during the installation. The moment is calculated with straight-forward and standard soils engineering formula.

The foundations are ideal for retaining walls, free standing light and sign structures, any vertical and angular leg structure, canopies, decks, small bridges, mobile homes or offices, satellite dish supports, garages, and etc. The bearing strength and overturning moment capabilities of the standard units range from 6000 lbs and 14,500 ft-lbs to 133,500 lbs and 3,000,000 ft-lbs (see page 3 of brochure). Values for these foundations for varying adhesion factors (Ca), friction angles (phi) and densities (gamma) are also easily determined (values for Ca = 500, gamma = 120 pcf and phi from 24° to 44° are enclosed). Relating capacities to applications the F1060406 would be ideal for a 35' light pole and the F1060606 for a 50' light pole.

The advantages are numerous but most importantly you have a rapid (approximately one-hour) installation with a single visit to the job site and a foundation of known strength.

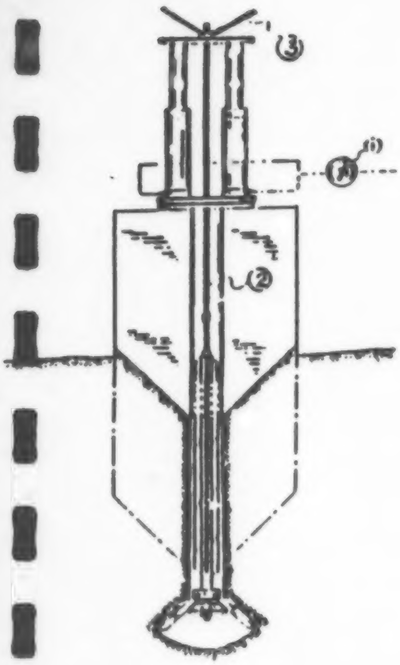
Together the anchors and foundations constitute a unique system designed to save both the customer and installer significant time and money.

Sincerely,

Pat

C P Tate
President

FOUNDATION INSTALLATION

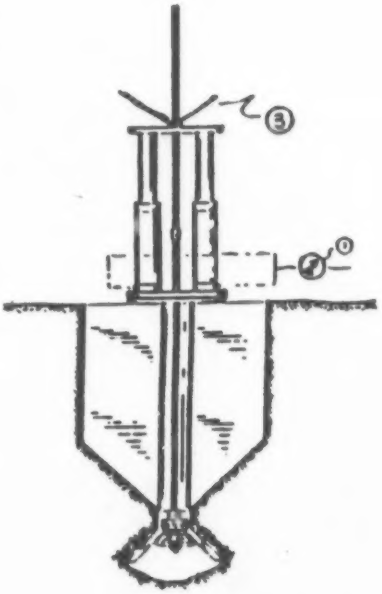


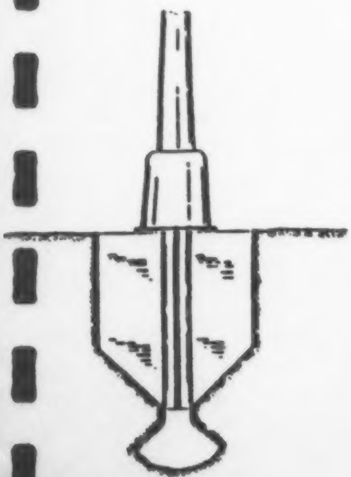
Step 1. Install foundation setting anchor per anchor installation procedures and set foundation into initial installing position securing installation hydraulics with spinner nut

- Install anchor
- Attach anchor rod extension ensuring coupler is completely and properly attached
- Lower foundation over setting anchor
- Attach installing hydraulics; align and center rod and hydraulics with the top of the foundation.
- Secure hydraulics and foundation into position with the spinner nut

Step 2. Push/pull foundation into its final installed position using installed anchors' strength and the force exerted by the installation hydraulics

- In a controlled manner push/pull foundation into place in 6 inch increments. At each incremental setting position monitor hydraulic gauge and allow pressure to drop and stabilize. (This indicates soil is consolidating/compacting; will occur within 10 seconds.)
- Full foundation installation will require several extensions of the installing hydraulics.
- Release hydraulic pressure, collapse cylinder, lower spinner nut, and resume installation
- When foundation has reached its installed position record the final gauge reading. With the appropriate hydraulic conversion table, record the force indicated by the gauge. (This is the load bearing strength of the foundation.)

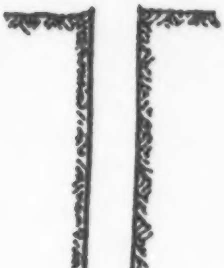




Step 3. Remove installing hydraulics and setting anchor; install structure using appropriate load transfer device.

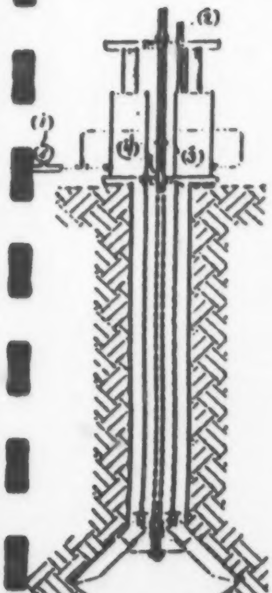
- Remove hydraulics and anchor rod extension
- Loosen anchor locking nut to allow anchor cone to drop to its lowest position
- Remove setting anchor by pulling on choke attached to centering column attachments
- Install and level structure with appropriate load transfer device.

ANCHOR INSTALLATION



Step 1. Auger Hole

- Diameter and Depth - per anchor spec (eg. A06X08 requires 6" diameter hole 8' deep)
- Inspect soils from bottom of hole and note augering resistance
- Check anchor for proper plate size (eg. plate 4 for poor soils; plate 1 for rock)
- Ensure hole alignment corresponds to requirements of structure. (location and angle correct)



Step 2. Install Anchor

- Inspect Anchor
  - Rod inserted into nut on cone
  - Coupler fully connected
  - Plate assemblies secured and plate ends resting on inclined surface of cone
  - Locking nut snug on setting column top cap
- Check system installation log for appropriate prerecorded information
  - Estimated soils type
  - Plate size
  - Anchor size and length
  - Setting range rod movement
  - Maximum setting pressure
- Lower anchor into augered hole - CAUTION - DO NOT DROP
- Attach installing hydraulics
- Set anchor in one inch increments
  - Control pressure and rod movement in a slow constant manner.
  - At each one inch rod extension stop movement and allow media to consolidate/compact. Pressure gauge will indicate consolidation/compaction process by gradually decreasing to a lower value. (This process should occur within 10 seconds.)
  - As the final set position is approached the gauge pressure will drop only slightly. This indicates complete consolidation/compaction of the media. In rock there will be little or no pressure drop during the setting process.
  - All pressure gauge readings and measured rod movements should be recorded prior to commencing with the next incremental movement.
  - The final gauge reading is directly related to the load bearing capacity of the anchor. (L.B.C.= .7 X final applied force)
  - Gauge readings can be converted into applied force by referring to the hydraulic conversion guide for setting device used. At each incremental setting tighten the anchor locking nut on the top cap. In the final installed position this must be accomplished prior to releasing the hydraulic pressure.
  - CAUTION - DO NOT EXCEED MAXIMUM SETTING PRESSURE/FORCE
  - Remove installing hydraulics and attach load transfer device

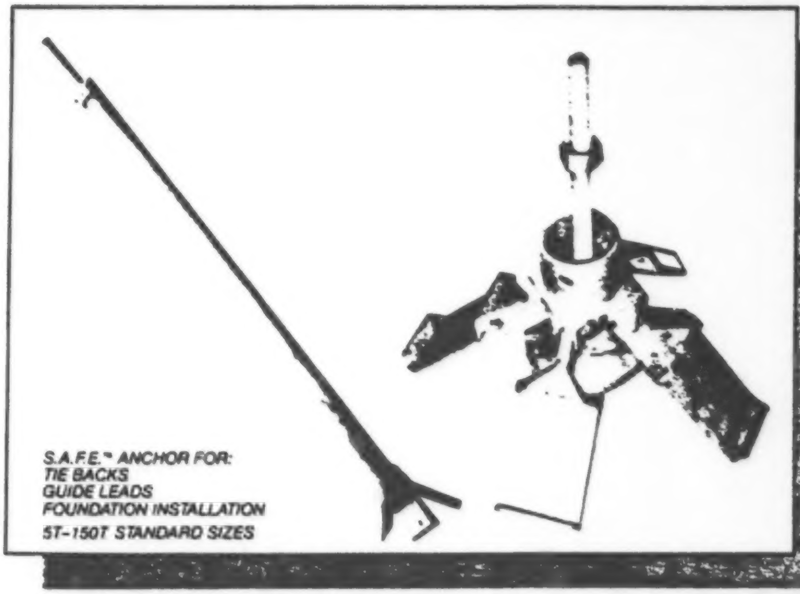
02150/FOU

BuyLine 6009

FOUNDATION & ANCHORING SYSTEMS

S.A.F.E.™ ANCHOR

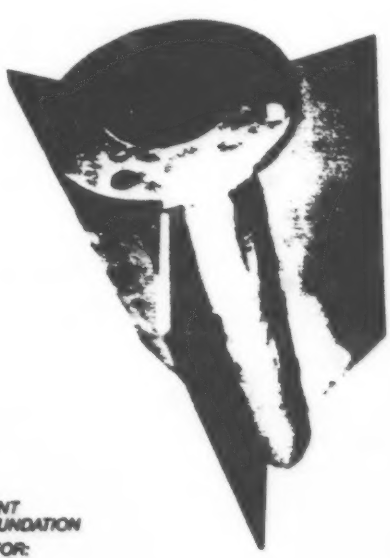
- ☐ SOLVES ANCHORING PROBLEMS IMMEDIATELY
- ☐ ATTACH LOAD AS SOON AS INSTALLED—NO WAITING
- ☐ KNOWN STRENGTH AT TIME OF INSTALLATION
- ☐ REDUCES OVERALL PROJECT TIME
- ☐ SAVES MONEY
- ☐ ALL WEATHER INSTALLATION
- ☐ MINIMUM CREW (2)
- ☐ AVAILABLE FOR EMERGENCIES
- ☐ UNLIMITED CAPACITY—SPECIAL DESIGN



S.A.F.E.™ ANCHOR FOR:
TIE BACKS
GUIDE LEADS
FOUNDATION INSTALLATION
5T–150T STANDARD SIZES

S.A.F.E.™ MOMENT STABILIZING FOUNDATION

- ☐ SOLVES FOUNDATION PROBLEMS IMMEDIATELY
- ☐ ATTACH STRUCTURE AS SOON AS INSTALLED—NO WAITING
- ☐ STABILIZES MOMENT FORCES
- ☐ KNOWN STRENGTH AT TIME OF INSTALLATION
- ☐ PROVIDES SIGNIFICANT PROJECT COST AND TIME SAVINGS
- ☐ REMOVABLE/REUSABLE S.A.F.E.™ ANCHOR USED TO INSTALL
- ☐ MINIMUM CREW (2)
- ☐ NO HEAVY EQUIPMENT REQUIRED
- ☐ REPLACES CONCRETE



S.A.F.E.™ MOMENT STABILIZING FOUNDATION

FOUNDATIONS FOR:
STREET LIGHTING
TRAFFIC LIGHTS
SIGNS
RETAINING WALLS

FOUNDATIONS & ANCHORS, INC.
620 Vanadium Road, Bridgeville, PA 15017 (412) 257-8889

© 1990 Foundations & Anchors, Inc.

PLATE SELECTION CHARTS

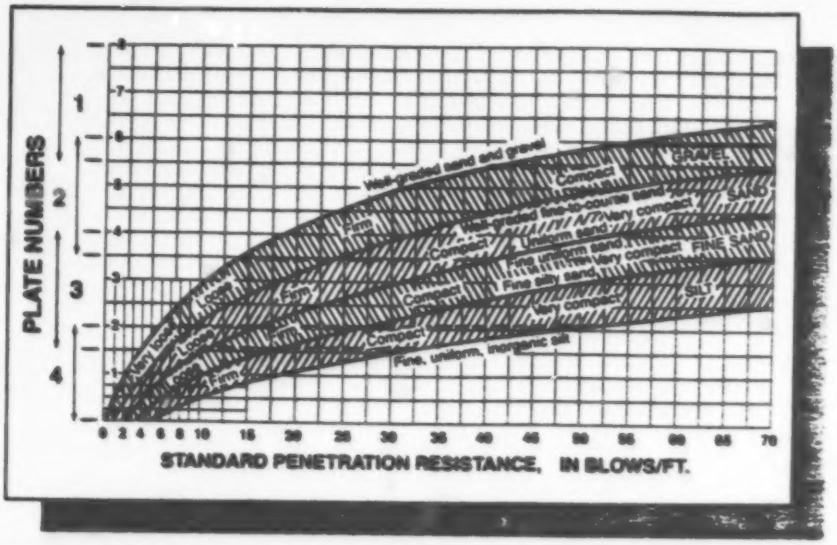
MR/MANUFACTURER

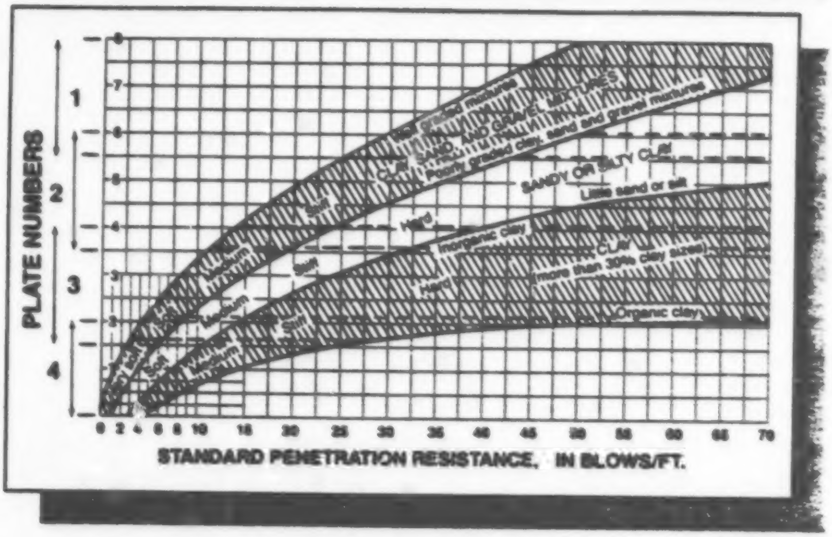
F & A, Inc. has an exclusive license to manufacture and market S.A.F.E.™ anchors and foundations. These devices are protected by US Patents and have been perfected during an eight year testing and development period. The anchors and foundations are available through a nation-wide network of distributors/installers.

F & A, Inc. will work with your design staff to ensure the most appropriate anchor and/or foundation devices are used for your application/project. Distributors/installers are available to meet your needs and/or to assist in training/certifying your personnel in S.A.F.E.™ product installation.

PP/PRODUCT PRESENTATION

S.A.F.E.™ Anchors are unique as they consolidate and compact the media (soil) in the vicinity of the hydraulically set plates thereby prestressing the media causing it to act as part of the anchor itself. The shear strength of the soil is used to provide holding power not available to friction anchors. The capacity of the unit is measured at time of installation. The load can be applied immediately as there is no requirement to wait for concrete or epoxy to cure. If the anchorage is temporary, the device can be removed and used again and again. A crew of two can install the anchor in an hour or less in all weather conditions.





S.A.F.E.™ ANCHORS

PRODUCT NUMBER	[redacted]	MAXIMUM SETTING FORCE LBS.
A04 × 08	[redacted]	15,000
A06 × 08	[redacted]	44,000
A10 × 08	[redacted]	90,000
A14 × 12	[redacted]	178,000
A16 × 12	[redacted]	294,000
A18 × 12	[redacted]	430,000

PRODUCT NUMBERING SYSTEM*

A 04 × 08

Anchor
Hole Diameter (in)
Plate Number (1–4)
Column Length (ft)

ANCHOR INSTALLATION

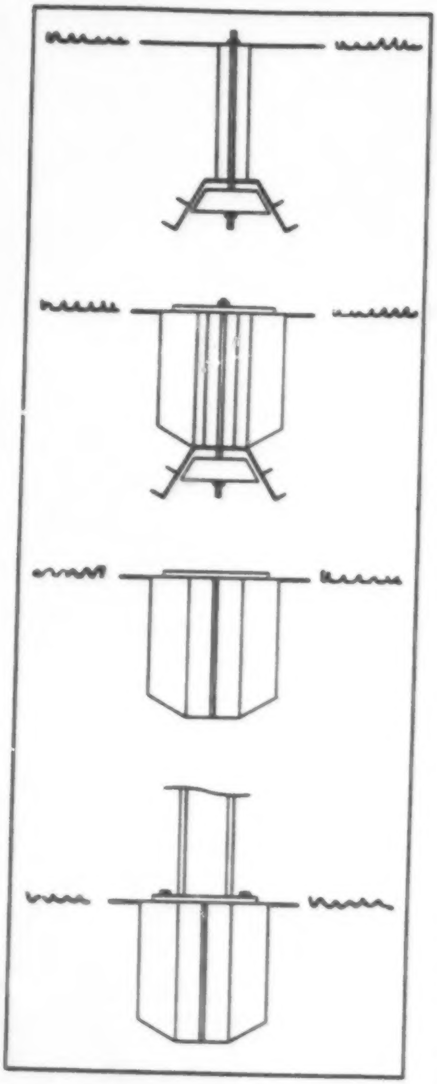
1. Auger Hole
2. Set Anchor Within Range
3. Read/Record Setting Force
4. Attach Load

*Note: For Anchors used to set foundations (1) add "F" after column length numbers and (2) use a setting column that is 2 feet longer than the foundation. e.g. to set a 10" Foundation 8′ long (F1100812) use anchor A10 × 10F.

Anchor strength = 0.7 × Setting Force (or Anchor Ultimate Strength, whichever is the lesser value)

AI/ASSEMBLY, INSTALLATION

SEQUENCE OF INSTALLATION



Foundation Installation

1. Auger Hole
2. Set Anchor
3. Set Foundation
4. Remove Anchor
5. Attach Structure

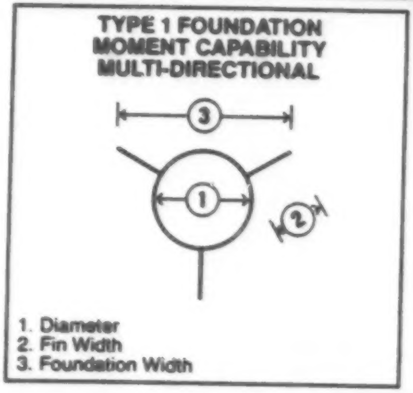
Notes: Protective base available.
(1) Add 2ft. to column length,
(2) Add "P" to product number, e.g. F1140818 for structure, F1141018P for same application with protective base.

OP/OVERALL PRODUCT

S.A.F.E.™ Moment Stabilizing Foundations are installed using a S.A.F.E.™ anchor which may then be removed and used for additional foundation installations. The bearing and uplift capacities are known precisely from the force required to set the foundation. The moment stabilizing capability is calculated from the existing soil conditions. The interchangeable fins allow a known moment load to be stabilized with appropriate safety factors. The foundation may be used immediately as anchor bolts do not need to be set in concrete or epoxy. A two person crew can install in an hour or less in all weather conditions.

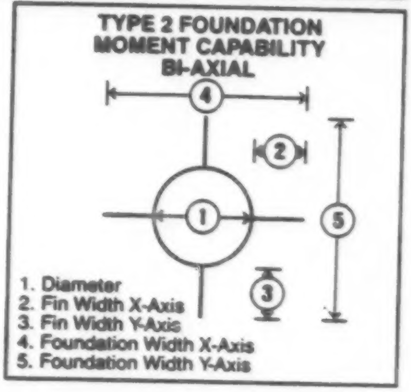
LOADING CAPACITIES—TYPE 1 FOUNDATIONS

PRODUCT NUMBER	AXIAL LBS.	SHEAR LBS.	TORSION MOMENT FT–LB.	OVERTURN MOMENT FT–LB.
F1060406	6,130	5,460	2,048	14,560
F1060606	14,000	9,446	3,542	37,800
F1100612	26,000	18,900	14,175	75,600
F1100812	34,000	33,600	25,200	179,200
F1140818	45,500	50,400	56,700	268,800
F1141018	63,000	78,750	88,594	525,000
F1161218	79,000	113,400	127,575	907,200
F1161624	133,500	268,800	403,200	2,867,200



TYPE 1 FOUNDATION
MOMENT CAPABILITY
MULTI-DIRECTIONAL

1. Diameter
2. Fin Width
3. Foundation Width



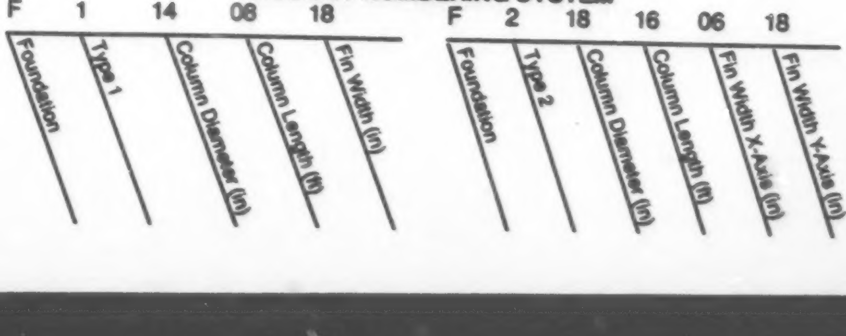
TYPE 2 FOUNDATION
MOMENT CAPABILITY
BI-AXIAL

1. Diameter
2. Fin Width X-Axis
3. Fin Width Y-Axis
4. Foundation Width X-Axis
5. Foundation Width Y-Axis

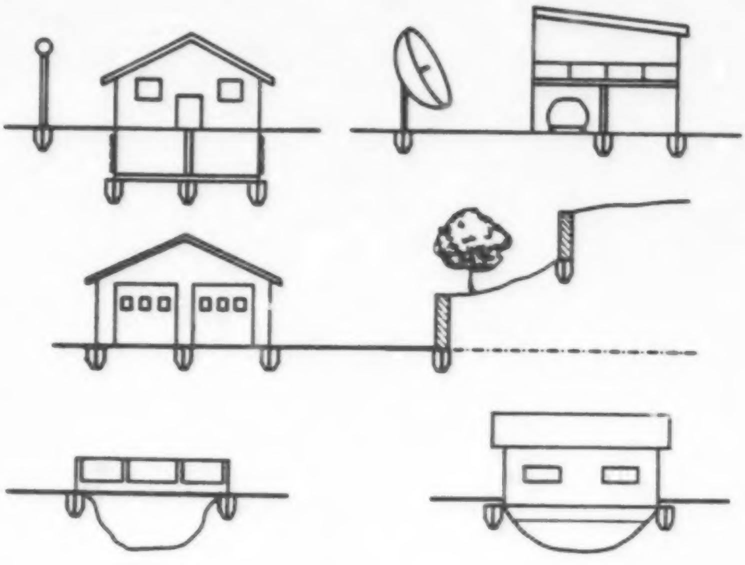
LOADING CAPACITIES—TYPE 2 FOUNDATIONS

PRODUCT NUMBER	AXIAL LBS	TORSION MOMENT FT–LBS	X-AXIS FT–LBS	Y-AXIS FT–LBS
[illegible]	76,500	367,212	1,677,312	2,394,112
[illegible]	101,500	[illegible]	1,792,000	[illegible]

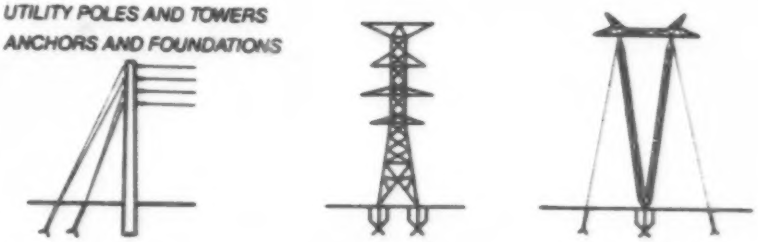
PRODUCT NUMBERING SYSTEM



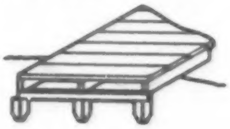
FOUNDATIONS FOR:



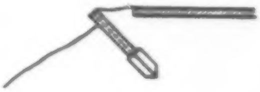
UTILITY POLES AND TOWERS ANCHORS AND FOUNDATIONS



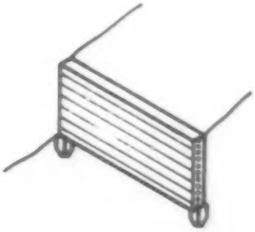
BRIDGE FOUNDATIONS



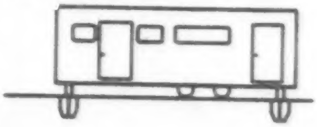
HIGHWAY REPAIR



RETAINING WALL



MOBILE HOME ANCHOR AND FOUNDATION SYSTEMS



TS/TECHNICAL SUPPORT

ITEM	[redacted]	GALVANIZING
Anchor	[redacted]	ASTM A-153
Foundation	[redacted]	ASTM A-153
Fins	[redacted]	ASTM A-153
Columns	[redacted]	ASTM A-153
Rod	[redacted]	ASTM A-153
Bolts & Nuts	[redacted]	ASTM A-153

CC/CODES, CERTIFICATION

Warranty

F & A, Inc. warrants that anchors and foundations will be free from defects and will perform as represented provided they are installed by qualified/certified installers in accordance with F & A, Inc.'s recommendations and applications and installation instructions. F & A, Inc. will refund the purchase price of any product proven defective but shall in no way be liable for indirect, consequential, special or resultant damages whether due to breach of warranty or negligence. F & A, Inc. makes no guarantee or warranty express or implied, including, without limitation, warranties of fitness or merchantability, with respect to their anchors and foundations.

USDA

REA accepted

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Hydraulic Tooling used for installation by Enerpac, a division of Applied Power, Inc.

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FOUNDATIONS & ANCHORS, INC.
620 Vanadium Road, Bridgeville, PA 15017 (412) 257-8889

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Steel anchors and foundations for above-ground structures

A new and revolutionary technology in underground foundations and anchors for above-ground structures has been developed and tested, and is now being marketed for major construction applications from buildings to bridges, from electric transmission towers to highway signs.

INCORPORATING such time and cost advantages as installation in one hour or less vs. the weeks of pouring and setting concrete, the new system embodies three elements never before available in anchors and foundations, according to its developer: (1) The devices actually increase the all-important shear strength of the surrounding soil; (2) They literally list the above-ground loads which can be handled, for during hydraulic installation the gauge reading stipulates the ultimate strength of the device; (3) they drastically reduce or eliminate the costly need to take soil samples to determine the soil's strength for anchoring or foundation functions.

Fig. 1 — Clockwise from top left, these pictures depict various steps in the installation process: augering a hole; hydraulics being used to install an anchor, noting the gauge reading which lists the force required and, thus, the ultimate load that anchor can hold; lowering a foundation over the anchor; bolting the base of a light pole to the top of the foundation.

Foundations & Anchors, Bridgeville, PA, the developers of the system, have replaced in-ground concrete with in-ground steel to provide patented structures that can handle virtually any load placed on the earth. For example, besides all bearing loads of a building and its contents, the steel anchors and foundations will resist snow, wind, uplift, axial, moment, shear and torsional loads.

U.S. and Canadian sales are projected to reach 5000 units a month within two years. If 10 percent of the market is captured for foundations and anchors, the new industry could be using 500000 tons of steel a year.

Typically, foundations and anchors account for between eight and 10 percent of a construction project's costs, so the savings possible with the new technology can be significant. The potential market is envisaged as covering the gamut of projects requiring underground support: billboards and signs, bridges, buildings, light poles, mobile homes, pipelines, power transmission towers, retaining walls, satellite antennas, traffic lights, underground and above-ground tanks.

The new foundation is basically a steel column with either three or four steel fins protruding from the sidewall. It supports structures by resisting all up, down, twisting and rotational motions. Column lengths and fin widths are determined by the load to be supported.

The new anchor consists of a round steel body, to which are attached four pivotable steel plates. The plates swing upward into the surrounding soil to permanently affix the anchor and, at the same time, consolidate and compact the soil for maximum anchoring strength.

Both devices, in all sizes, are made of ASTM A36 steel for its 36 ksi (248 MPa) yield strength. Service life can be customized to project need via the steel's corrosion protection, which can range from galvanizing and coatings to full cathodic treatment, where another metal is sacrificed to corrosion instead of the steel.

Both the anchor and foundation concepts have been tested in-ground for more than two years. Test installations include: Donaldson's Crossroads Shopping Center, in Peters Township, Pa., foundations for 10 and 15 m light poles; Northern Virginia Electric Co-op (with approval of the Rural Electrification Administration), anchors for transmission tower guy wires; Penn Power (in Western Pa.), anchors for utility poles; Allegheny River Lock-and-Dam No. 6, for anchoring guy lines at a hydroelectric station. Each test installation resulted in cost savings of at least 50 percent, compared to conventional devices.

Installation involves several steps, normally takes an hour or less. In anchor installation, a two-man crew augers an eight-foot-deep hole, places the anchor in it, attaches the hydraulics which force-spreads the

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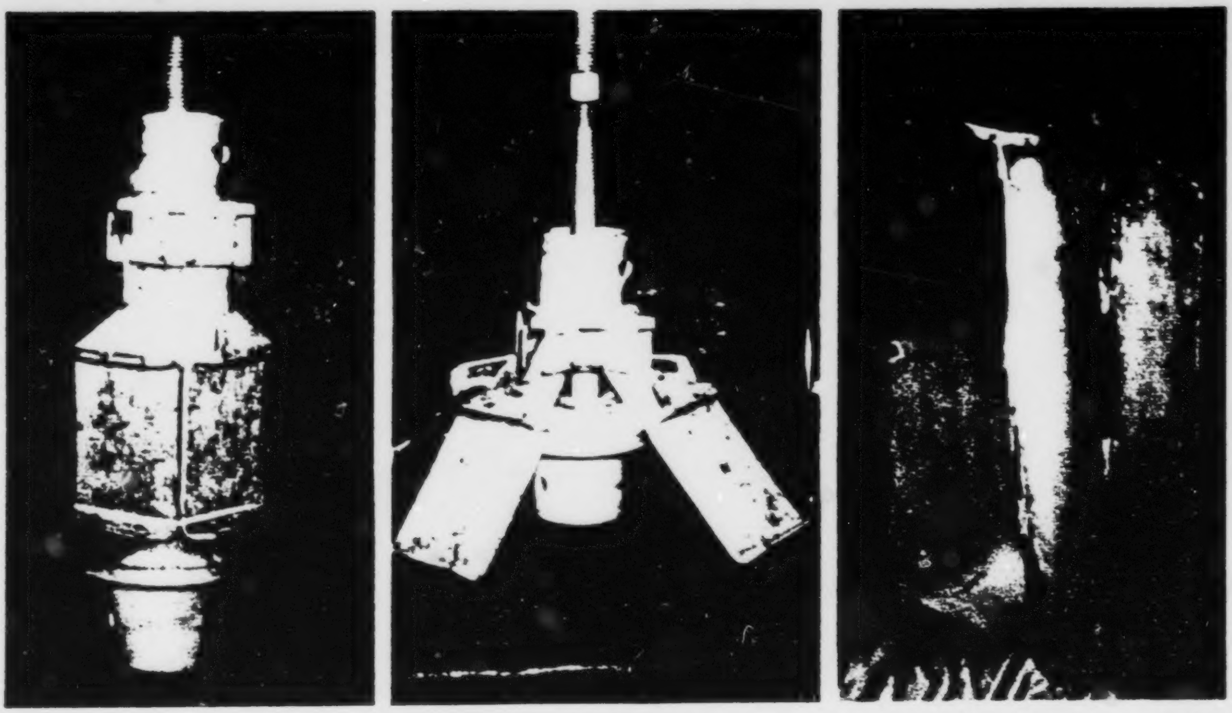


Fig. 2 — These three photos show (left to right) a steel anchor compacted for insertion into the ground; the anchor with steel plates extended upward, as they would be underground, to attain maximum holding capacity; and the steel foundation with its protruding fins.

plates. (With hydraulics capable of providing in excess of 1800000 kgf, anchors and/or foundations can be built to handle virtually any size or type of load.) The hydraulic gauge is then read—the force required to set the anchor is the ultimate load the anchor can hold. The anchor is locked into position, the hydraulics removed, the load transfer assembly attached and, finally, the above-ground structure attached.

Installing a foundation follows the same anchor-placing procedure through removal of the hydraulics. Then the foundation is lowered to ground level over the anchor, hydraulics are reattached, foundation is pushed down to the desired depth, and a strength gauge reading is taken. The hydraulics are removed, the anchor is removed through the center of the foundation, and the above-ground structure is attached to a load transfer assembly.

POINTS OF INFORMATION

Since the concept is new and unique, construction specifiers and contractors, and those not well versed in soil engineering, may be interested in the following points of information.

- Soil engineers report that, increasingly, especially in metropolitan and suburban areas, there is limited availablity of construction sites with ideal soil conditions. To a large extent, it is the weak, loose sand, clay, loam and inorganic silt soils, with lower load bearing values and higher potential for soil settlement, that are still available. Accordingly, it is important that anchors and foundations now have the capability of being able to improve soil characteristics.
- In the past, determination of a soil's characteristics was made by soil analysis, involving costly core boring tests of bearing capacity, shear strength, moisture content, particle size and composition, cohesion, density and acidity. The problem was that the act of taking a sample automatically disturbed the soil, so test findings were often inaccurate. Overdesign of foundations was performed regularly as a safety factor. Far better is a system that, in its application, increases and then determines the exact strength of the soil.
- As soil engineers know, the principal factor in the behavior of soil under above-ground loading is its shearing strength. The idea is to raise this strength through controlled consolidation and compaction, to virtually eliminate all settlement after the load is applied. In fact, the true objective is to prestress the soil and anchor/foundation beyond the loads to be placed upon it.
- In determining the anchor and foundation sizes required, it is always important to know two factors. First, the weight of the above-ground structure itself plus snow loads, wind loads, moving and other loads must be taken into account. Second, one must compensate for all forces that can be exerted on an above-ground structure — axial, moment, shear and torsional loads.
- In a benefit of the new system not mentioned previously, each anchor can take four different sets of plate sizes to accommodate different soil conditions and achieve maximum holding capacity. Should the hydraulic gauge indicate that the anchor/soil strength is not sufficient, the plates can be replaced with a set of the larger sizes. The strength indicated with the largest plate at an extension of 45 degrees is, automatically, the best that can be achieved for those soil conditions.

APPENDIX 2.3
MISCELLANEOUS VENDOR CORRESPONDENCE

CANTECH

Cantech Corporation
200 Wright Avenue, Unit # 9
Dartmouth, Nova Scotia, B3B 1W5
Phone (902) 468-5114
Fax (902) 468-5105

Mr. Don Leger

C/O Fenco/Shawnigan

Halifax, NS

Phone: (902) 421 – 3200 Fax: (902) 425 – 4464

Good Morning,

As per our phone conversation yesterday afternoon, below you will find the information we discussed. If you have any other questions, please feel free to contact Dave Kramer, or myself.

Anderson Greenwood Model # 93 (10"x12")

Body : *304 Carbon Steel* Seat Material : *Teflon*

Diaphragm : *Buna N* Seals, Etc. : *Buna N*

Set Pressure : *5 PSI Maximum*

*$14,900 **

Anderson Greenwood Model # 93T (10"x12")

Body : *304 Stainless Steel* Seat Material: *Teflon*

Diaphragm : *Teflon* Seals, Etc. : *Teflon*

Set Pressure : *5 PSI Maximum*

*$19,500 **

Anderson Greenwood Model # 93T (12"x16")

Body : *304 Stainless Steel* Seat Material: *Teflon*

Diaphragm : *Teflon* Seals, Etc. : *Teflon*

Set Pressure : *5 PSI Maximum*

*$26,400 **

** Please note, the above prices are budgetary only and include inflation and are based on the purchase of only one valve. Please request firm pricing before ordering. All Taxes Extra (If Applicable).*

Yours truly,

Michael W. McCarthy, Inside Sales

APPENDIX 2.4
CANMET REPORTS

Fuel Reburning Performance of Mine Methane

F. Preto, J.K. Wong, H. Whaley and G.K. Lee

ABSTRACT

The mine return air from the Lingan and Phalen mines in Cape Breton, N.S., has a methane content of 0.4% by volume. The two mines produce 335 m^3/s of this ventilation air. In addition, mine drainage methane is produced at a rate of approximately 1.0 m^3/s (potentially 2.0 m^3/s) with methane content of 50% by volume.

A research program using the CCRL pilot-scale research boiler was undertaken to evaluate the feasibility of utilizing mine return air as combustion air for Lingan Generating Station as well as using the mine drainage methane stream as a reburn fuel to enhance NO_x removal.

The mine drainage methane "as collected" gave marginal performance as a reburning fuel. NO_x reduction was limited to approximately 12%. Concentrating the methane to 100% increased NO_x reduction to 25%. Combining the mine drainage methane and mine return air streams and using them for combustion air offers a potential NO_x reduction of 5 - 10%. The introduction of methane into the boiler will lower SO_2 and could also lower CO emissions and improve carbon burnout.

March 1991

Combustion and Carbonization Research Laboratory (CCRL)
Energy Research Laboratories, CANMET,
Energy, Mines and Resources Canada,
Ottawa, Ontario, K1A OG1.

INTRODUCTION

This combustion research project was undertaken by the Combustion and Carbonization Research Laboratory (CCRL), Energy Research Laboratories (ERL) of CANMET for Asea Brown Boveri (ABB) Combustion Services Division as part of a study commissioned by The Committee on Atlantic Coals to assess the technical and economic feasibility of supplying and using Lingan and Phalen mine methane at the Lingan Generating Station. Currently, mine methane is vented to the atmosphere. Methane contributes to the greenhouse effect at a rate over 20 times greater than carbon dioxide. In addition methane combustion is cleaner than coal combustion, producing less SO_2, NO_x, CO2 and ash per unit of energy. The use of mine methane in combustion air, as reburn fuel, or a combination of the two has the potential to reduce both greenhouse and acid gas emissions.

The mine return air (MRA) stream under consideration consists of the return ventilation air from the Lingan and Phalen mines. The methane content of these streams is 0.4%. The MRA volume is approximately 165 m^3/s from the Lingan mine and 170 m^3/s from the Phalen mine. The mine drainage methane (MDM) stream consists of collections from mine drainage systems. Such a system is currently in place at Lingan, producing approximately 1.0 m^3/s at a methane content of 50% by volume. The potential of an equal amount exists for a planned drainage system at the Phalen mine.

The scope of this work included evaluation of the technical feasibility of utilizing mine return air as combustion air and use of a mine drainage methane stream as a reburn fuel to enhance NO_x removal. The objective of the project was to evaluate the combustion performance of the Lingan/Phalen/Prince coal used at Lingan G.S. when used in conjunction with:

(i) MRA as combustion air;
(ii) MDM as a reburn fuel;
(iii) concentrated MDM as reburn fuel; and
(iv) combined MDM and MRA as combustion air.

Tests were to be conducted at the methane levels noted above with the NSPC coal blend fired under combustion conditions similar to Lingan G.S..

This report gives of review of fuel reburning, describes the CCRL pilot-scale combustion research facilities, the experimental procedures used in this study and gives an evaluation of the test results.

Literature Review

Fuel staging or "reburning" involves injecting fuel into a secondary combustion zone downstream of the primary combustion zone. In this zone, sub-stoichiometric reactions between NO and hydrocarbon radicals, provide the basis for the method of NO reduction by reaction with CH_i radicals, e.g.

$$NO + CH \rightarrow HCN + O$$

$$NO + CH_2 \rightarrow HCN + OH.$$

The cyanides thus formed subsequently form amines which can react further with NO to produce N_2. High gas temperature is desired in the fuel-rich NO reduction process. Following the reduction of NO, further air injection into the furnace is necessary to complete the combustion of the "reburn" fuel. In order to avoid subsequent formation of thermal NO, heat extraction from this final, lean combustion zone is vital.

A number of experimental studies [Bartok et al. (1987), Chen et al. (1986, 1989), Knill and Dekker (1988), Lanier et al. (1988), Mullholland and Hall (1985), Takahashi et al. (1981), Toqan et al. (1987), Wendt et al. (1973)] have demonstrated the successful application of this process of NO reduction. A comprehensive review of work up to 1987, focusing on coal as the reburning fuel, is given by Knill (1987). As is the case with other reviews of this technology, Knill (1987) had difficulty arriving at definite conclusions due to the fact that in the various studies, different significant parameter ranges were considered. The following is a review of the general understanding of fuel reburning.

The combustion parameters which determine the effectiveness of NO_x reduction are the initial NO_x level that is to be reduced, stoichiometry, residence time, and temperature of the reburning zone. Parameters associated with the subsequent burnout zone such as temperature and stoichiometry appear to have only minor effect.

The residence time coupled with temperature defines the kinetics of the reduction reactions. It is desirable to inject the reburning fuel as close to the main heat release zone as possible to take advantage of the higher temperature. With natural gas as the reburn fuel, NO_x reduction is favoured at temperatures above 1200°C due to an increase in the rate of the NO/HC and HCN/O reactions. Chen et al. (1989) shows that reburning temperature is very important up to 1200°C but the effect of temperature diminishes beyond this point. The effect of temperature when using coal as the reburning fuel has not been as well established due to possible reactions involving fuel nitrogen. It appears though that temperature is less important for reburning with gaseous fuels than it is for solid fuels.

The influence of fuel type on reburning effectiveness is the subject of some debate. Several studies have suggested that hydrocarbon gases are more effective than coal [Chen et al. (1986), Mullholland and Hall (1985), Roby and Bouwman (1986), Wendt et al. (1973), Bartok et al. (1987)]. Bartok et al. (1987) have shown this to be true particularly at the short residence times required by many boiler configurations. Nevertheless, there is no definitive agreement on fuel type and the effectiveness of coal as a reburning fuel has its proponents (Knill (1987)). It appears that coals with high volatile matter and high char reactivity can be very effective reburning fuels due to increased HC radical production.

Regardless of fuel type, sufficient hydrocarbon radicals must be available. General consensus is that at least 10% of the total fuel input should be injected as reburning fuel to obtain worthwhile NO_x reduction. There is very little work reported with reburn fuel levels less than 10%. Takahashi et al. (1981) reports NO_x reduction of 50% using 10% reburn fuel. In some cases, reburn fuel fractions as high as 30% have been proposed. Bartok et al. (1987) report optimum NO_x reduction when using approximately 20% reburn fuel (natural gas). The preferred working range seems to be 10 to 30%, as greater reburn fractions may affect main flame stability and require major modifications to the primary and secondary burners. Without modifications, decreased firing density in the primary zone could lead to carbon burnout problems.

The stoichiometry of the reburning zone is also important, as sufficient oxygen must be available to convert HCN to NCO. Using coal as the reburn fuel seems to require careful control of reburning zone stoichiometry with values of 0.65 to 0.95 [(Knill (1987), Bartok et al. (1987)] being optimum. The latitude is much greater using natural gas as the reburn fuel with some reduction reported for stoichiometric ratios as high as 1.25 (Bartok et al. (1987).

The mixing between NO_x formed in the primary combustion zone and the reburning fuel must be rapid and intense in order to promote the reactions to convert NO_x. This is generally not a problem in pilot scale units but could be significant in utility scale boilers. Mixing can be improved by increasing the momentum of the injection stream, e.g. by increasing the quantity of transport air. This may have drawbacks in the form of early fuel oxidation which would reduce reburning effectiveness.

Fuel injected as a reburning agent must have sufficient residence time to ensure complete reaction. A residence time as short as 50 ms is sufficient for natural gas (Bartok et al. (1987)

whereas coal requires at least 400 ms. Takahashi et al. (1981) indicate that residence times of 100 ms are required even for gaseous fuels. Some coals require residence times as long as 1 second. Consideration of residence time is extremely important for retrofit applications, because in some cases upper furnace volumes may be restricted.

The importance of the initial NO_x levels (i.e. produced in the primary zone) in determining reburning effectiveness is significant if the initial levels are already low. Published pilot plant work indicates that 50% reduction is not possible for initial NO_x levels less than 140 ppm. For initial NO_x levels below 250 ppm, reburn fuel nitrogen content may limit further reduction. Takahashi et al. (1981), using a pilot plant, reports that above these low levels, reduction efficiency is independent of initial NO_x level. Knill and Dekker (1988) suggest that utility scale results may contradict some pilot plant data.

Fuel reburning is currently the subject of a proposed U.S. Department of Energy demonstration program in which the NO_x in a coal-fired cyclone boiler would be reduced by natural gas injection corresponding to 20% of the total heat input to the boiler.

In summary, significant NO_x reduction by fuel reburning with natural gas appears to have the following requirements:

-although very little has been reported using low levels, reburn fuel should be at least 10% of furnace input;
-reburn zone temperature should be 1200°C or higher;
-residence time for the reburn fuel should be at least 100 ms;
-the magnitude of the initial NO_x levels is significant for low levels (below 150 ppm).

EXPERIMENTAL

Equipment

The CCRL pilot-scale research boiler is a pulverized coal-fired boiler incorporating two opposing low-swirl burners (Figure 1). The furnace is U-shaped and consists of a vertical refractory shaft and a vertical steam boiler, which are connected at the bottom through a horizontal refractory tunnel.

This boiler can be fired by the twin low-swirl burners located in three basic positions; known as the I, J and U configurations. Highly reactive fuels will burn efficiently when fired in the I configuration. However, for fuels that are difficult to burn, residence times and combustion zone temperatures can be increased by locating the twin burners in the U configuration. Intermediate residence times can be obtained by locating the burners in the J configuration. It is estimated that at full load and with the burners located in the I configuration, the combustion chamber residence time will be about one second. This residence time will increase to about three seconds with the burners located in the U configuration. The combustion chamber heat release rate is about 0.35 MJ/m^3s. The furnace was operated in the J configuration for all the trials performed during this investigation.

The three sections of the furnace are designed to operate at pressures up to 2.5 kPa. At the full-load firing rate of 2.5 GJ/h (0.7 MW), the boiler generates about 730 kg/h of steam at 690 kPa. It is possible to control the furnace exit temperature by adding cooled-wall panels in the refractory shaft or by partially insulating the water walls of the boiler.

When the boiler is operated in the pulverized-coal mode, crushed coal is supplied to the furnace from a 4500-kg hopper, mounted on an electronic weigh scale, through a variable speed worm feeder to a ring-and-roller type of pulverizer, which is normally swept and pressurized by air at temperatures up to 230°C. If necessary, the pulverizer can be swept and pressurized with a mixture of air and flue gas at temperatures up to 400°C. The pulverizer contains a variable speed motor-driven classifier for controlling coal fineness and a riffle at the pulverizer outlet proportions the coal to each burner.

A forced-draft fan supplies air to the air heater at 7 kPa. The air, on leaving the heater, is divided into three systems: primary air to the pulverizer , secondary air to the burners and cooling air to the test air heater. The last stream, after leaving the test air heater, can either be exhausted to the atmosphere or blended with the primary air supply to the pulverizer. Secondary air is supplied to the burner at temperatures up to 260°C. The burner is a stainless steel pipe (2 in. I.D.), with a bluff-body at the end to produce a better mixture of fuel and combustion air.

The research boiler is manually controlled, except for electrical interlocks to ensure that safe start-up and shutdown procedures are followed.

Operating Procedure

The following procedure, with minor variations, is used for all combustion trials:

(a) Before each trial, all boiler and air heater fireside surfaces are thoroughly cleaned and the furnace bottom is lined with a refractory blanket.

(b) Sufficient coal is bunkered to provide enough fuel for steady state operation (7h).

(c) At start-up, the cold boiler is preheated in order to stabilize steaming rate and pressure. All continuous monitoring analyzers and instruments are also activated and allowed to warm.

(d) The test fuel is fed to the boiler at the desired specified feed rate and excess air level (4% O_2).

(e) MRA feed is simulated by introducing methane (from cylinders) into the primary combustion air stream. MDM/reburn feed is simulated by introducing natural gas at the desired methane/air ratio into the slag probe port on the east (water-wall side) side of the boiler. Tertiary air is then injected to restore the desired excess air level (4% O_2).

(f) Boiler panel readings are monitored continuously and recorded every half hour. Specified methane and coal feed rates and excess air levels are maintained as steady as possible for the duration of the trial.

(g) The following are recorded:

-A composite sample of crushed coal is taken at the pulverizer inlet.

-Moisture and sieve analyses of pulverized coal are taken at the pulverizer outlet.

-The oxygen content of the flue gas is measured continuously by a Dynatron oxygen analyzer and a paramagnetic monitor.

-The nitrogen oxide (NO_x) content of the flue gas is measured continuously by a chemiluminescent analyzer.

-Carbon monoxide and dioxide (CO and CO_2) are measured continuously by infrared analyzers.

-Sulphur dioxide is measured continuously by a non-dispersive ultra-violet analyzer.

-The fly ash loading in the electrostatic precipitator (ESP) is measured, when possible, by an isokinetic sampling system. Sample analysis includes unburnt char.

-The aerodynamic size distribution of the fly ash is determined in an Anderson fractionating sampler and in a Cascade cyclone sampler.

(h) Once a test series is completed, the furnace is shut down and allowed to cool overnight. The following day the furnace bottom is removed, the duct works are dismantled and the ash in the furnace bottom and duct work are photographed, collected weighed and sampled. As part of this analysis the following is carried out:

-Fouling of heat-transfer surfaces is evaluated by visual examination. The chemical composition of ash build-up on a simulated superheater is determined.

-Slagging propensity is determined by examining the thickness, physical structure, chemical composition and melting characteristics of ash deposits selected from various parts of the furnace.

Baseline Conditions

The baseline conditions for the tests were:

- ▸ Coal Feed: NSPC Lingan/Phalen/Prince Blend - Analyses as per Tables 1 through 3
- ▸ Nominal Total Heat Input: 1785 MJ/h
- ▸ Excess Air: Oxygen in Flue Gas, 4.0%
- ▸ Initial NO_x Level: 886 ppm
- ▸ MRA Injection with Primary Air
- ▸ Reburn Gas Injection at 1200°C
- ▸ Reburn Residence Time: > 1 second

RESULTS & DISCUSSION

Boiler Operation

The mine methane tests, summarized in Table 4, can be grouped into three categories: MRA (0.5 - 1.0% methane) trials in which the mine methane is injected into the primary air; the NG trials in which the MDM stream is concentrated to 100% methane and injected as reburn fuel; and the MDM trials in which an MDM (50% methane) stream is injected "as is" as reburn fuel. In addition, one run was carried out with both MRA and MDM streams.

The boiler input streams, shown in Table 5, were adjusted in order to maintain the desired baseline conditions. For the reburn tests, the total heat input varied between 1721 and 1762 MJ/h. Coal feed rate adjustments during the MRA trials proved difficult and so the total heat input rose according to the additional fuel (methane). In all cases though, the baseline excess air level was maintained between 3.5 and 4.0% O_2. The temperature at the reburn fuel injection location was held near 1200°C as shown in Table 6.

All trials were run in the J-furnace configuration. Once steady state conditions were achieved, the flame was bright clean and stable. The intensity of the flame increased slightly with the addition of MRA. The addition MRA or MDM did not have any adverse effects on boiler operation.

MRA Trials

Two specific MRA trials were carried out in which a dilute methane stream was introduced into the primary air. These tests were carried out at methane concentration of 0.5 and 1.0% and load fractions of 3.9 and 8.1% respectively. The addition of methane caused the NO_x levels to drop by about 5%. There does not seem to be an appreciable difference for an MRA stream with 0.5 or 1.0% methane. The displacement of coal by methane reduces the amount of fuel nitrogen NO_x entering the boiler, however it's effect on "thermal nitrogen" NO_x is probably minimal. Unfortunately this test program did not allow for additional MRA tests to explore this further.

Reburn Trials

Four NG trials were carried out in which 100% natural gas was used to simulate concentrated

MDM as reburn fuel. The boiler heat input due to methane was varied from 4.0 to 9.2%. In all cases significant NO_x reduction was observed. At methane load of 9.2%, NO_x reduction of 25 to 30% was observed. As per the MRA trials displacement of some coal by methane resulted in a slight drop in the flue gas SO_2 concentration.

Four MDM trials were carried at essentially the same load fractions as for the NG trials. There were no significant deviations observed in boiler operating conditions between the two sets of trials. Some NO_x reduction was observed, however, the magnitude was on average 10% lower than for the NG trials. Reburning is affected by local stoichiometry, therefore it can be postulated that the air accompanying the methane is responsible for the negative effect. In terms of reburning, the MRA+MDM test behaved as an MDM test. As Table 7 shows, the results for run FR8 (MDM) are comparable to those for run FR9 (MDM+MRA).

The reburn data is plotted in Figure 2. The separation between the MDM and the NG trials is quite obvious. Using pure natural gas as the reburn fuel, a load fraction of 10% would give a NO_x reduction of approximately 30%, which compares favourable with results reported by other researchers (Bartok et al. (1987)). If the same load fraction were available as MDM only (i.e. 50% methane), then the NO_x reduction would drop to approximately 15%. The difference between MDM and NG is very evident from Figure 3.

Based on the MDM data given in the Introduction, if both Lingan and Phalen mines methane drainage systems were functioning at full capacity, the MDM generated would correspond to approximately 8% of the heat input for one boiler at Lingan G.S. Interpolating from Figure 2, this would represent approximately a 12% NO_x reduction if used as MDM and a 25% reduction if the stream were concentrated to 100% methane. Combining the MDM and MRA streams and introducing the mixture as combustion air would probably reduce NO_x by 5 - 10%.

Flue Gas Emissions

The flue gas analyses for each run are summarized in Table 8. The SO_2 concentrations show a clear downward trend when plotted against methane heat input (Figure 4) due to the displacement of coal by methane.

The CO level, also in Table 8, appears to have remained steady (24 - 32 ppm) throughout all testing. A plot of CO level versus methane heat input (Figure 5) does however show a trend. Increasing the methane input reduces the CO level slightly due to the fact that methane burns to completion better than coal.

Carbon Burn-out

The carbon content of the fly ash is shown in Table 9 along with the fly ash mass loading. The data are somewhat erratic, however when the carbon content is combined with the mass loading and plotted as shown in Figure 6, the overall carbon loss is reduced as the amount of methane is increased. The effect of increasing methane is therefore to increase the combustion efficiency for the coal.

CONCLUSIONS

Combustion tests have been carried out on a pilot-scale research boiler to determine whether mine drainage methane from Lingan and Phalen mines is suitable as reburning fuel/combustion air for the Lingan Generating Station. The following conclusions may be drawn from these tests:

1. Using MDM "as collected" for reburn fuel, based on availability corresponding to 8% of the heat input to a single boiler would result in approximately a 12% reduction in NO_x emissions from that boiler.

2. Concentrating the MDM to 100% methane and then using it as reburn fuel would result in a potential NO_x reduction of approximately 25%.

3. The MDM and MRA streams may be combined and introduced as part of the combustion air without adverse effects to boiler operation. NO_x reduction in such a case would be in the 5 to 10% range.

4. Substitution of methane for coal will result in a proportional reduction in SO_2 emissions as well as a slight reduction in CO emissions and improved carbon burnout.

REFERENCES

Bartok, W. et al. (1987), "Gas Reburning-Sorbent Injection", Gas Research Institute Report 88/0058.

Chen, S.L., et al. (1986), Twenty-first Int. Symposium on Combustion, Combustion Institute, p. 1159.

Chen, S.L., et al. (1989), "Optimization of Reburning for Advanced NO_x Control on Coal-Fired Boilers", JAPCA, 39(10), p. 1375-1379.

Knill, K.J. (1987), "A Review of Fuel Staging in Pulverised Coal Combustion Systems", IFRF Doc. No. G 13/a/3, IFRF, IJmuiden.

Knill, K.J., Dekker, J.S.A. (1988), "Evaluation of the Effect of Process Variables on NO_x and Nitrogen Species Reduction in Coal Fuel Staging", IFRF Doc. No. F 037/a/20, IFRF, IJmuiden.

Lanier, W.S., Mullholland, J.A., Beard, J.T. (1988), Twenty-first Int. Symposium on Combustion, Combustion Institute, p. 1171.

Mullholland, J.A., Hall, R.E. (1985), Joint EPA-EPRI Symposium on Stationary Combustion NO_x Control, Vol. 1, No. 4, Boston.

Roby, R.J., Bouwman, C.T. (1986), "Effect of Hydrocarbon on Nitric Oxide Removal in Rich Premixed Flames", Spring Technical Meeting of Canadian/Western States Combustion Institute, Banff.

Takahashi, et al. (1981), "Development of Mitsubishi MACT In-Furnace NO_x Removal Process." Mitsubishi Heavy Industries Ltd Technical Review, Vol. 18 No. 2.

Toqan, M.A., et al. (1987), Joint EPA-EPRI Symposium on Stationary Combustion NO_x Control, New Orleans.

Wendt, J.O.L., Sternling, C.V., Mafovich, M.A. (1973), Fourteenth Int. Symposium on Combustion, Combustion Institute, p. 897.

Table 1. Coal Analyses

COAL: NSPC Blend Lingan/Phalen/Prince		CCRL: A251(a)-90	
Moisture, wt% (as received)	6.84	Sulphur Forms (dry), wt%	
Proximate, wt%, dry:		Sulphate	0.05
Ash	15.25	Pyritic	2.38
Volatile Matter	34.36	Organic	0.96
Fixed carbon (diff)	50.39	Ash Analysis, %	
Ultimate, wt%, dry:		SiO_2	46.36
C	69.67	Al_2O_3	23.37
H	4.54	Fe_2O_3	24.90
S	3.39	TiO_2	0.85
N	1.29	P_2O_5	0.23
Ash	15.25	CaO	0.90
Oxygen (by diff)	5.86	MgO	0.97
Heating Value, MJ/kg	28.88	SO_3	0.59
Ash Fusibility, °C		Na_2O	0.48
Oxidizing:		K_2O	2.57
Initial Deformation	1363	Sum	101.23
Softening Spherical	1388		
Softening Hemisph.	1407	Screen Analysis, %	
Fluid	1421	+25.4 mm +1"	27.27
Reducing:		+19.1 +3/4	35.87
Initial Deformation	1110	+12.7 +1/2	47.27
Softening Spherical	1279	+6.4 +1/4	64.68
Softening Hemisph.	1329	+3.2 +1/8	78.61
Fluid	1335	-3.2 -1/8	21.39
Free Swelling Index	3.5		
Equil. Moisture	5.84	Mean Reflectance,%	0.74
Chlorine in coal, %	0.30		

Table 2. Coal Size Distribution (Out of Pulverizer)

Coal Fineness, wt%	
+100 mesh	0.2
-100+140	6
-140+200	21
-200+325	20
-325+400	6
-400	47
-200 mesh	73

Table 3. Coal Moisture Content

Run	Coal Moisture, wt%
FR1	1.54
FR2, FR3	1.20
FR4	1.13
FR5 to FR12	0.80

Table 4. Summary of Mine Methane Runs

Run	Description
FR1	Coal Only, Baseline Run
FR2	MRA - Methane in Combustion Air; 3.9% of Load; 0.5% CH_4 Content
FR3	MRA - Methane in Combustion Air; 8.1% of Load; 1.0% CH_4 Content
FR4	NG - Pure Methane as Reburn Fuel; 5.5% of Load
FR5	NG - Pure Methane as Reburn Fuel; 9.2% of Load
FR6	NG - Pure Methane as Reburn Fuel; 4.0% of Load
FR7	NG - Pure Methane as Reburn Fuel; 9.2% of Load - BOILER 75% LOAD
FR8	MDM - 50/50 Mixture Methane/Air as Reburn Fuel; 9.0% of Load
FR9	MDM - 50/50 Mixture Methane/Air as Reburn Fuel; MRA - Methane in Combustion Air; 0.5% CH_4 Content Total Methane = 12.3% of Load
FR10	MDM - 50/50 Mixture Methane/Air as Reburn Fuel; 3.8% of Load
FR11	MDM - 24/76 Mixture Methane/Air as Reburn Fuel; 9.3% of Load
FR12	MDM - 47/53 Mixture Methane/Air as Reburn Fuel; 3.5% of Load

Table 5. Boiler Input Flow Rates

Run	Coal (Dry), kg/h	Primary Air, m^3/h	Sec. Air, m^3/h	CH_4, m^3/h	MDM Air, m^3/h	Tertiary Air, m^3/h
FR1	60.85	349.0	264.3			
FR2	61.06	354.9	385.0	1.93		
FR3	61.06	338.8	428.8	4.28		
FR4	56.06	336.2	297.5	2.63		17.1
FR5	53.67	337.9	262.5	4.22		50.2
FR6	56.74	330.2	332.5	1.70		27.5
FR7	41.47	322.2	227.5	3.40		48.8
FR8	55.06	330.7	315.0	4.19	4.22	57.6
FR9	55.06	328.2	350.0	5.95	4.22	57.6
FR10	57.93	325.7	371.0	1.81	1.81	15.2
FR11	54.26	331.9	264.3	4.22	13.59	55.2
FR12	58.43	327.7	343.0	1.70	1.90	43.3

All air/gas flow rates at STP (0°C, 101 kPa)

Table 6. Flue Gas Temperatures

Run	TW, °C	TE, °C	TSB, °C	TOP, °C	FLUE, °C
FR1	1404	-	1050	717	290
FR2	1417	1206	1068	737	305
FR3	1473	1254	1118	754	325
FR4	1414	1231	1127	707	313
FR5	1320	1156	1054	672	296
FR6	1427	1232	1081	719	321
FR7	1425	1213	1076	661	295
FR8	1428	1245	1033	743	337
FR9	1453	1287	1044	771	357
FR10	1505	1321	1073	777	362
FR11	1432	1255	1084	728	321
FR12	1477	1303	1105	739	348

Location	TW	TE	MDM Injection	TSB	TOP	FLUE
Distance from Burner, m	1.26	2.83	2.88	3.67	5.04	10.43

Table 7. Effect of Methane Injection on NO_x Reduction.

Run	Total Heat Input, MJ/h	CH_4 Input, % of Load	CH_4 Stream, CH_4 content,%	NO_x, ppm	NO_x Reduction,%
FR1	1785.	0.0	0.0	886	-
FR2	1858.	3.9 MRA	0.5	839	5.3
FR3	1943.	8.1 MRA	1.0	842	5.0
FR4	1732.	5.5 NG	100.0	736	16.9
FR5	1721.	9.2 NG	100.0	605	31.7
FR6	1721.	4.0 NG	100.0	755	14.8
FR7	1330.	9.2 NG	100.0	664	25.0
FR8	1762.	9.0 MDM	49.8	751	15.2
FR9	1827.	8.7 MDM +3.6 MRA	49.8	772	12.9
FR10	1753.	3.8 MDM	50.0	862	2.7
FR11	1742.	9.3 MDM	24.0	699	21.1
FR12	1762.	3.5 MDM	47.0	825	6.9

Table 8. Flue Gas Composition

Run	O_2, %	CO_2, %	CO, ppm	NO_x, ppm	SO_2, ppm
FR1	3.9	14.5	32	886	2500 est.
FR2	3.8	14.6	29	839	2500
FR3	3.7	14.5	28	842	2266
FR4	4.0	14.3	25	736	-
FR5	3.7	14.2	27	605	2502
FR6	4.0	14.3	31	755	2241
FR7	3.8	14.2	31	664	2040
FR8	3.5	14.6	25	751	2331
FR9	4.0	14.0	26	772	2195
FR10	3.6	14.7	27	862	2338
FR11	3.6	14.3	24	699	2627
FR12	4.0	14.4	26	825	2305

Table 9. Operating Conditions and Fly Ash Loading

Run	Total Heat Input, MJ/h	Flue Gas, m^3/MJ	Steam Rate, kg/MJ	Fly Ash Mass Loading, g/MJ	Combustible in Fly Ash,%
FR1	1785	0.304	0.169	0.98	0.58
FR2	1858	0.303	0.167	0.57	2.75
FR3	1943	0.301	0.176	0.86	2.35
FR4	1732	0.307	0.172	0.48	1.98
FR5	1721	0.301	0.152	0.46	2.15
FR6	1721	0.307	0.165	0.52	2.37
FR7	1330	0.301	0.196	0.22	1.67
FR8	1762	0.297	0.149	0.47	2.40
FR9	1827	0.306	0.155	0.48	2.40
FR10	1753	0.298	0.165	0.69	0.78
FR11	1742	0.298	0.154	0.67	1.89
FR12	1762	0.306	0.169	0.72	3.18

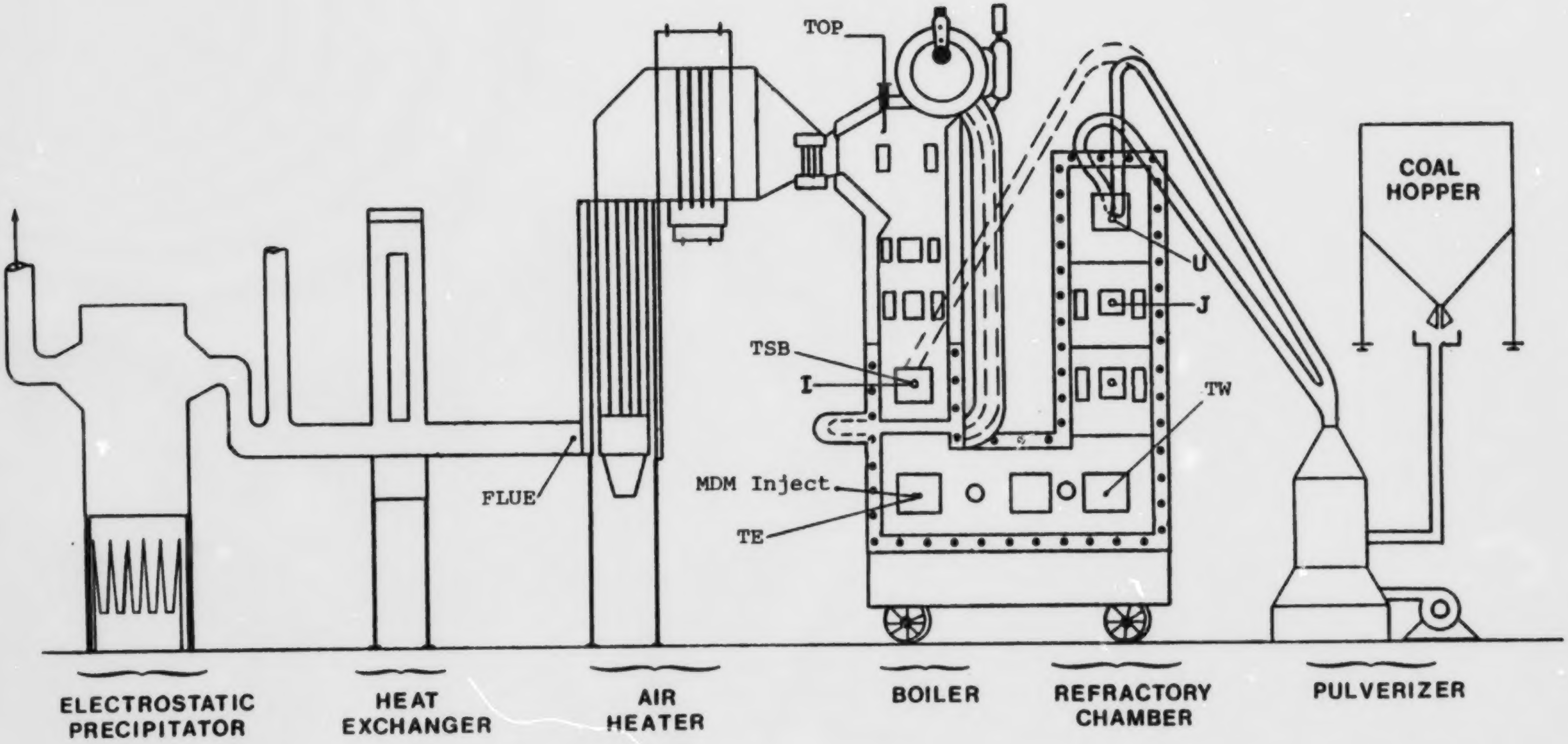


Figure 1. Schematic of CCRL pilot-scale research boiler

Figure 2. Effect of Mine Methane on NO_x Reduction

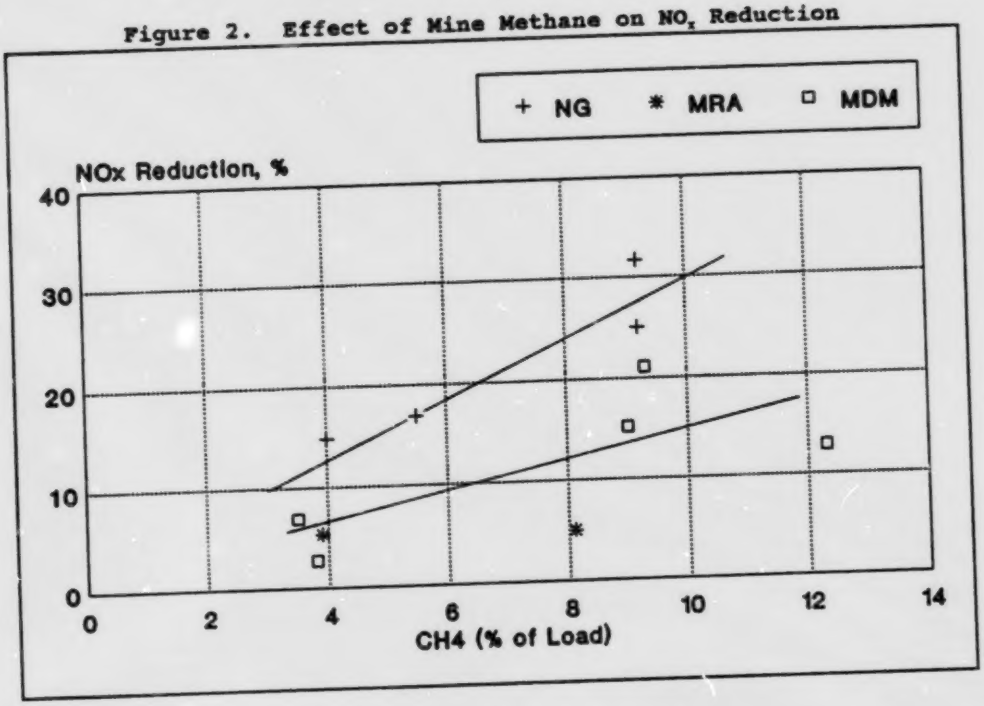


Figure 3. Effect of Methane Content on NO_x Reduction

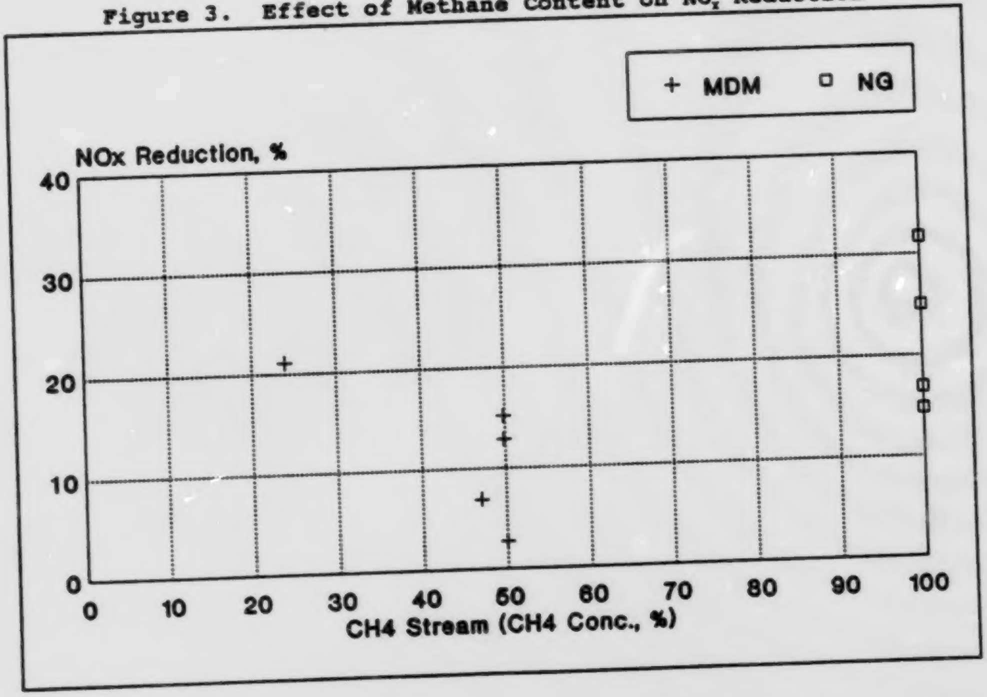


Figure 4. Effect of Methane Load on SO_2 Emissions

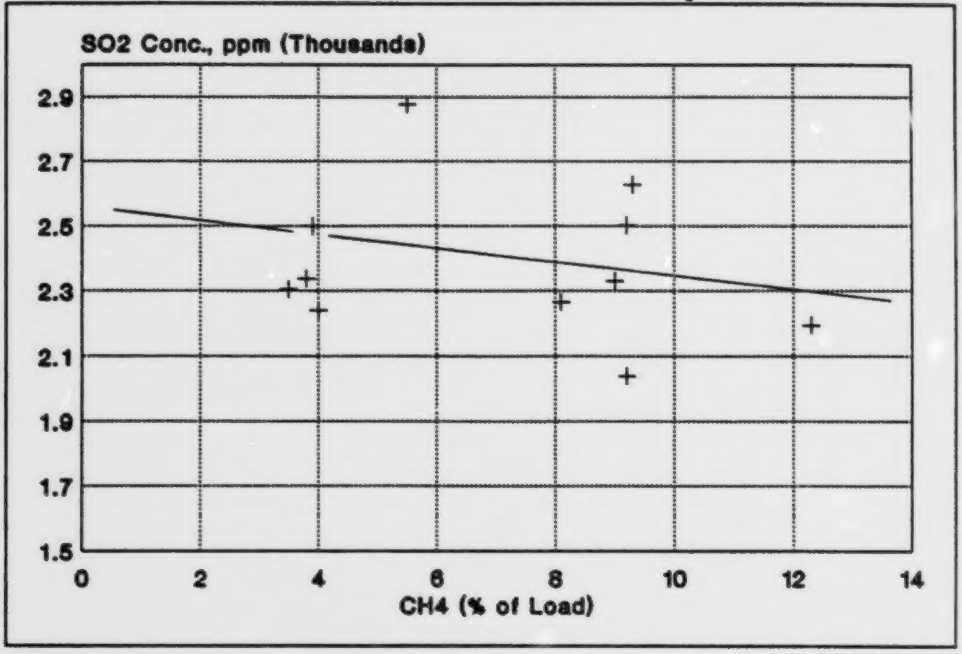


Figure 5. Effect of Methane Load on CO Emissions

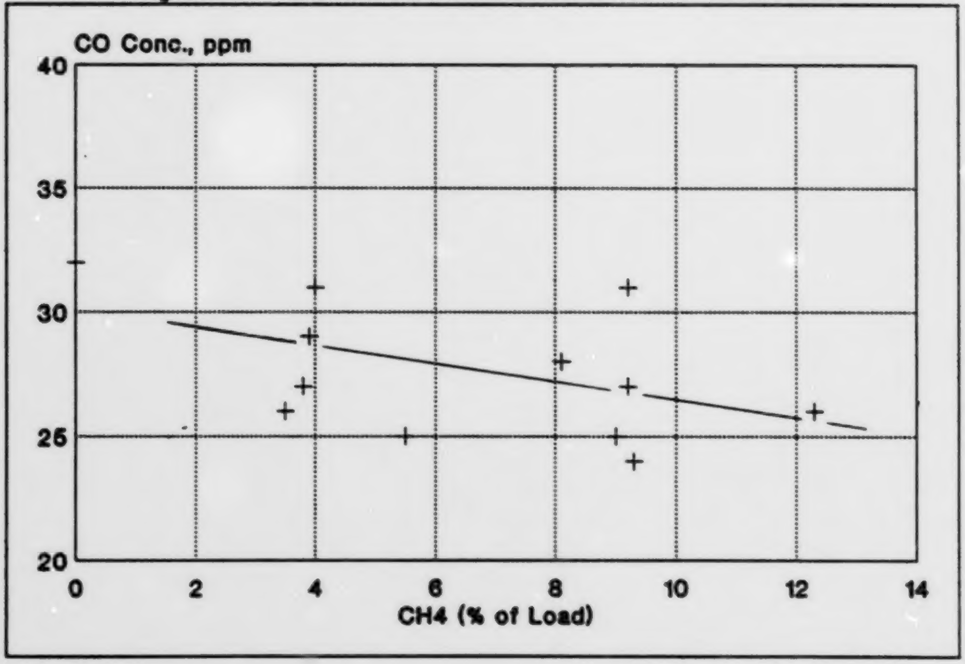
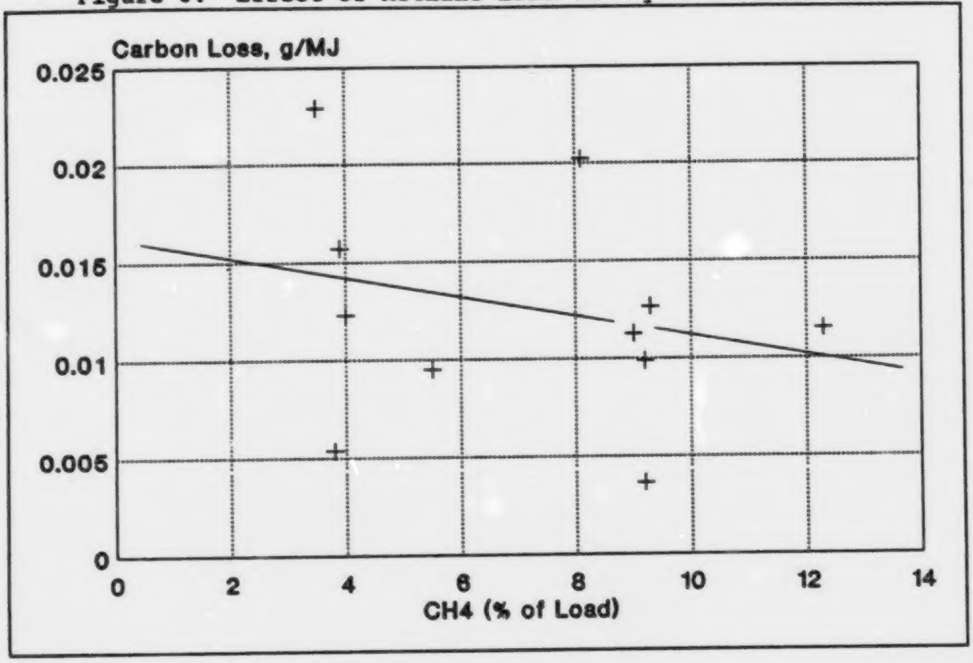


Figure 6. Effect of Methane Load on Fly Ash Carbon Loss



Report on Methane Slippage
When Using Mine Methane as Combustion Air

F. Preto

Abstract

The Committee on Atlantic Coals has commissioned a study, undertaken by Fenco Shawinigan Engineering Limited (FSEL) to assess the technical and economic feasibility of supplying and using Lingan and Phalen Mine Methane at Lingan Generating Station as combustion air to reduce the environmental impact of both greenhouse and acid gas emissions.

Interim results suggest that the most favourable option is to blend all mine air streams into one containing approximately 0.8 - 1.0 volume % methane and duct this stream to the power plant where it will be admitted into the boilers as secondary air.

This report comments on methane slippage, i.e., the possibility that methane may escape the furnace unburnt. The time required for complete combustion of the methane is estimated as approximately 30 ms under worst case conditions. The residence time available is in the order of 2-3 seconds, therefore methane slippage in extremely unlikely.

March, 1991

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Introduction

Methane has been identified as a chief culprit in "global warming" with a potential effect over 20 times greater than carbon dioxide. Coal mining is a significant emitter of atmospheric methane. At the Lingan and Phalen mines in Cape Breton, Nova Scotia, mine ventilation air typically contains 0.4 - 0.6% methane. In addition, mine drainage streams contain approximately 50% methane. With both mines fully operational, the combined flow rate that may be expected is approximately 380 m^3/s with a methane concentration of 0.66%. This represents a methane release of over 2.5 m^3/s.

The Committee on Atlantic Coals has commissioned a study, undertaken by Fenco Shawinigan Engineering Limited (FSEL) to assess the technical and economic feasibility of supplying and using Lingan and Phalen Mine Methane at Lingan Generating Station as combustion air to reduce the environmental impact of both greenhouse and acid gas emissions.

Interim results suggest that the most favourable option is to blend all mine air streams into one containing approximately 0.8 - 1.0 volume % methane and duct this stream to the power plant where it will be admitted into the boilers as secondary air. It is vital to the success of this project that the methane introduced burn completely as any methane slippage would negate some benefits of the project.

The basic criteria for efficient combustion may be summarized as:

-The combustion system must ensure that good mixing of air and fuel occurs and that the fuel has enough time to react. The reaction time is itself extremely dependent on temperature.

-The proper operating conditions, i.e., relative quantities of fuel and air, must be maintained.

The latter criteria is generally the responsibility of the furnace operator and can be easily monitored and controlled.

This report will comment on the former requirement, i.e., are the time and temperature requirements met for complete combustion of 1% by volume methane introduced with secondary air.

Methane Properties

Methane (CH_4) exists as a gas at room temperature and is the principal constituent of natural gas. Methane boils at 112 K. It forms explosive mixtures with air at concentrations above 5.53 percent by volume. The upper flammability limit, i.e., the concentration at which stable combustion is achieved, is 14.85% at room temperature.

The lowest temperature at which it is possible to ignite a fuel by applying an external source of heat is knwon as the ignition temperature. The ignition temperature of methane is 811 K. The temperature for spontaneous ignition (autoignition) of methane in air is 905 K (Gaydon, A.G. and Wolfhard, H.G., 1979). At this temperature methane will burn without support from an external heat source (flame).

Preferential Combustion

Regardless of fuel type, the bulk of combustion is completed in gas phase reactions. Liquid fuels vaporize in the hot furnace environment, and it is this vapour that actually burns. Solids are pyrolyzed, releasing volatile components that burn in the gas phase. The remaining char is then usually gasified (by oxygen or water) to carbon monoxide.

In the design of furnaces and boilers, it is commonly recognized that natural gas has a faster heat release rate (Lawn, 1987) than either oil or coal. This is due to the absence of a devolatilization step, which for PF coal-fired systems requires approximately 100-200 ms.

The devolatilization of coal has been studied by many researchers who have attempted to quantify the numerous species released. Devolatilization can be divided into two stages; first, the lower-molecular weight hydrocarbons are given off; second the heavier hydrocarbons, aromatics and tars are evolved [Smoot and Smith, 1985]. Devolatilization therefore results in the evolution of organics that are more complex than methane. Their complete oxidation would therefore involve many more reactions, which may be expected to require more time to complete than the oxidation of methane.

For these reasons one could conclude that methane will burn faster than coal and that therefore introduction of methane into a coal flame would result in the preferential combustion of methane. Methane slippage would therefore be unlikely.

Reaction Kinetics

In attempting to estimate a specific rate of reaction, one must set out the reaction mechanism involved. The combustion of methane may be generalized as follows:

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

The actual reaction mechanism is much more complex. Smoot and Smith (1985) note that this apparently simple oxidation requires a mechanism involving over 300 reactions. For methane, as with most hydrocarbons, oxidation reactions tend to proceed rapidly to the point where CO is formed and then to slow down until CO burnout is achieved. As a result, the kinetics for methane combustion may be approximated by CO kinetics. The kinetic expression for the reaction of CO is given by (after Hottel et al. 1965):

$$\frac{-dX_C}{dt}=12x10^{10}\left(\frac{P}{R_1T}\right)^{1.8}X_CX_O^{0.3}X_W^{0.5}\exp\left(\frac{-16,000}{RT}\right) \quad (1)$$

where X_C, X_O, X_W are the mole fractions of CO, O_2 and water vapour, T is the absolute temperature (K), P is the absolute pressure (atm), t is the time in seconds, R is the gas constant (1.986 kcal/kg mol K) and R_1 is also the gas constant (82.06 atm cm^3/g mol K). Assuming isothermal conditions, the change in CO concentration may be obtained from

$$\frac{X_{c,f}}{X_{c,i}}=\exp(-Kt) \quad (2)$$

where K, the rate constant (s^{-1}) is

$$K=12x10^{10}\left(\frac{P}{R_1T}\right)^{0.8}X_O^{0.3}X_W^{0.5}\exp\left(\frac{-16,000}{RT}\right) \quad (3)$$

Lingan Generating Station Data

The Energy and Environmental Research Corporation (Irvine, California) has developed a computer program (PCHT2D) to allow evaluation of existing boiler furnaces by identifying furnace and unit performance changes over a wide range of boiler operating conditions. The PCHT2D model is based on a two-dimensional (2D) zone heat transfer model that allows estimation of the furnace temperature distribution from the boiler furnace design and the operating conditions. The model includes a state-of-the-art procedure for calculating heat exchange by radiation, which is the dominant parameter at the temperatures typical of boiler furnaces. The major outputs of the model are axial and radial gas temperature profiles in the furnace and distributions of heat flux. The model has been validated by testing carried out by CANMET at various NSPC units, including the Lingan Generating Station (Preto et al., 1990).

The PCHT2D model divides the furnace volume into a grid as illustrated in Figure 1. The model can then predict temperature and heat/material fluxes in each zone of the grid. The data shown in Figures 2 through 5 was obtained from PCHT2D (Granatstein, 1991) for operation at 100% and 65% of full load. Data is only shown for the zones at and above the over-fire air location. The data therefore represents the least advantageous conditions in terms of residence time as well as temperature.

Figures 2 and 3 show the temperatures at two load conditions (100% and 65%). The temperature is above the autoignition temperature for methane in the entire furnace. As expected, the temperatures are slightly higher for full load conditions. The temperature predictions of PCHT2D have been validated by testing (Preto et al., 1990).

Figures 4 and 5 show the average cumulative gas residence times for each zone, again at the two load conditions (100% and 65%). At full load (Figure 4), the total gas residence time is approximately two seconds. This increases to approximately three seconds at 65% load. This data is typical of PF coal-fired power generation boilers (2-3 seconds from Lawn (1985)).

Figures 4 and 5 also show the predicted concentration of unburnt volatiles at the over-fire air location (bottom of grid). The volatile levels are extremely low and this is the last level at which any significant levels are predicted. Given that volatiles are more complex organics than methane, it is unlikely that methane itself would survive beyond this point.

Reaction Time

The following are typical data for the Lingan GS:

Excess air: 18%
Oxygen content of flue gas: 3.27% by volume
Water content of flue gas: 7.83% by volume
Lowest temperature (at the furnace exit for 65% load): 926 K

If one assumes that the methane is all converted to CO, then the initial concentration can be assumed as being 1.0%. Assuming a final concentration of 10 ppm is desired, the following is the time required for this degree of conversion:

Equation (2) becomes:

$$0.00001/0.01 = \exp(-Kt)$$

$$Kt = -\ln(0.001)$$

$$t = 6.908 / K.$$

Equation (3) may then be solved:

$$K=12x10^{10}\left(\frac{1}{(82.06)(926)}\right)^{0.8}0.0327^{0.3}0.0783^{0.5}\exp\left(\frac{-16,000}{(1.986)(926)}\right)$$

which results in

$K = 249.68\ s^{-1}$

and

t = 0.028 s.

Thus, even at the worst case conditions in the furnace, the reaction time for complete combustion of the methane is less than 30 ms. This is considerably less than the estimated available residence time of 2-3 seconds.

Fuel Reburning

Fuel reburning can be an effective method of reducing NO_x emissions. Reburning involves injecting fuel into a combustion zone downstream of the primary combustion zone. This reburning zone is operated sub-stoichiometrically so that hydrocarbon radicals from the reburning fuel may reduce NO formed in the primary combustion zone.

A primary consideration of reburning is to insure that the reburn fuel has enough time to burn completely. Bartok et al. (1987) reported on trials carried out with natural gas and with reactive coals. Their results suggest that a residence time of 50 ms was adequate for natural gas, whereas coal required at least 400 ms to achieve complete combustion.

Reburning trials have been carried out at CANMET's Combustion and Carbonization Research Laboratory using coal from Lingan as the primary fuel and methane as the reburning fuel. The extent to which complete combustion of natural gas was obtained may be seen in Figure 6. The level of CO at the furnace exit is shown plotted against the amount of methane injected. As the amount of methane (as a percentage of total fuel input) increased, the CO level dropped slightly. This confirms that methane "slippage" was not occurring.

Summary

Mine methane injected as combustion air into boilers at the Lingan Generating Station may be expected to burn completion due to the following reasons:

1. The mean gas temperature from the injection point through to the exit of the furnace is higher than the autoignition temperature for methane.

2. The residence time required for complete combustion of methane is estimated as approximately 30 ms. The average gas residence time from the injection point forward is estimated as 2-3 seconds.

3. Methane is a much simpler hydrocarbon than the volatiles given off by the coal. The volatiles burn to completion, therefore methane slippage is extremely unlikely.

References

Bartok, W. (1987), "Gas Reburning-Sorbent Injection", Gas Research Institute Report 88/0058.

Gaydon, A.G. and Wolfhard, H.G. (1979), *Flames: Their Structure, Radiation and Temperature*, Chapman and Hall.

Granatstein, D. (1991), Nova Scotia Power Corporation, private communication.

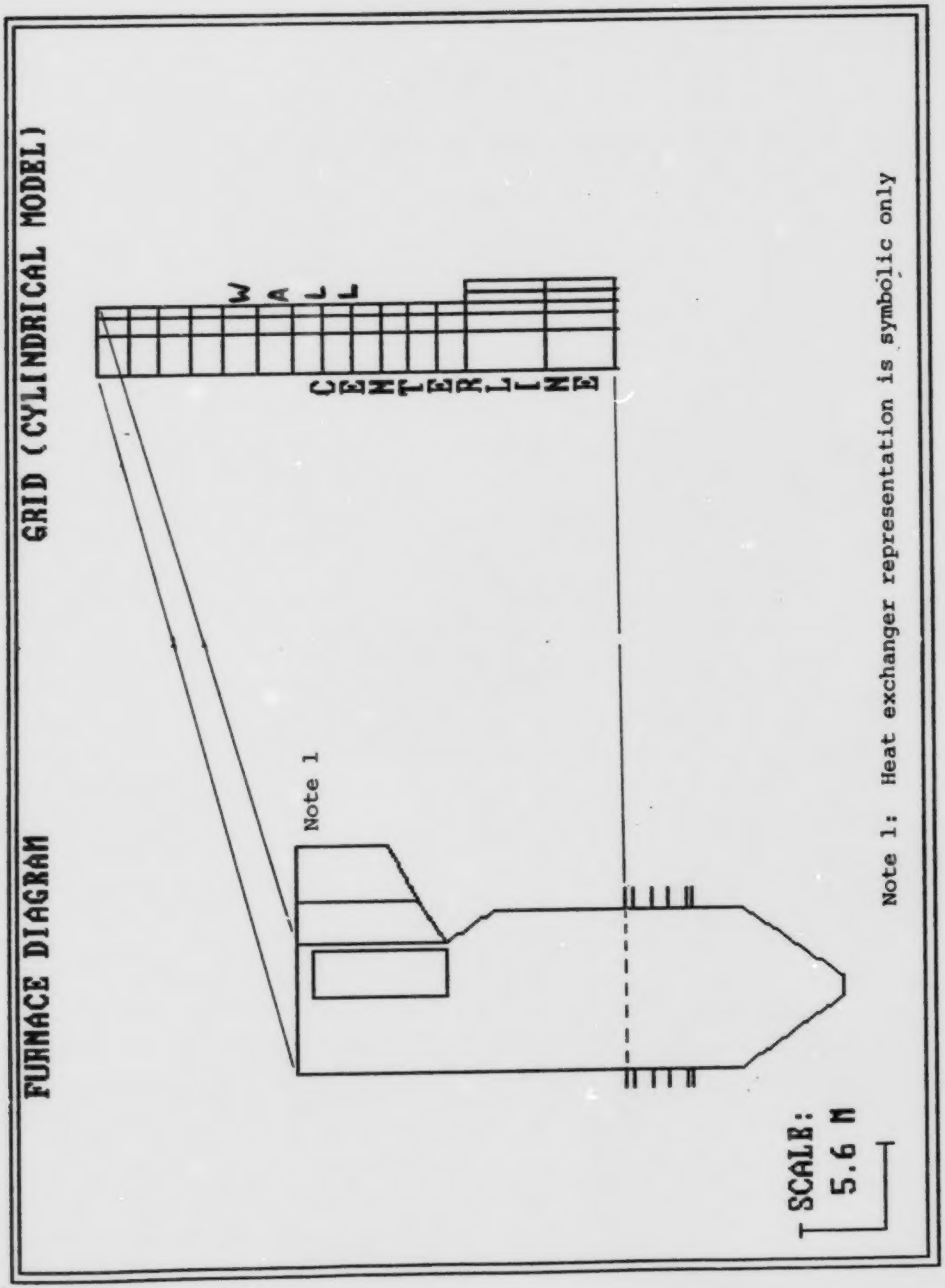
Hottel, H.C. et al., (1965) 10th Int. Symposium on Combustion, Combustion Institute, Pittsburgh, pp. 111-121.

Lawn, C.J. (1987), *Principles of Combustion Engineering for Boilers*, Academic Press, London, U.K.

Preto, F., Philp, R., Lee, G.K. (1990), "Furnace Temperature Measurements for Heat Transfer Model Validation", ERL Report 90-53(CF).

Smoot, L.D. and Smith, P.J. (1985), *Coal Combustion and Gasification*, Plenum Press.

Figure 1. PCHT2D Generated Grid Representation of Lingan Furnace.



Note 1: Heat exchanger representation is symbolic only

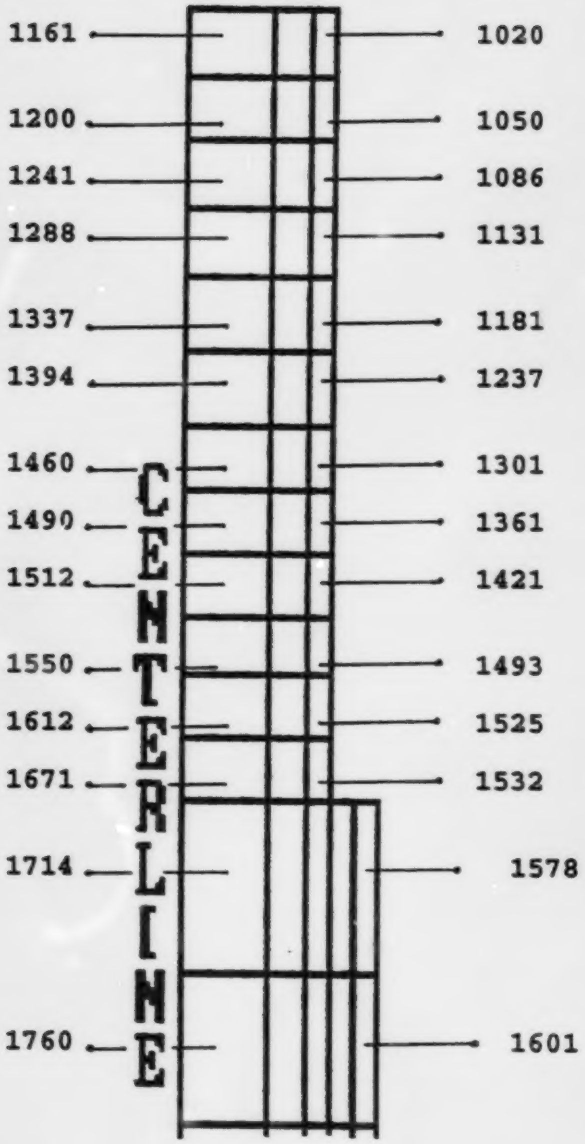


Figure 2. Temperature (K) Distribution for Lingan Boiler at 100% Load.

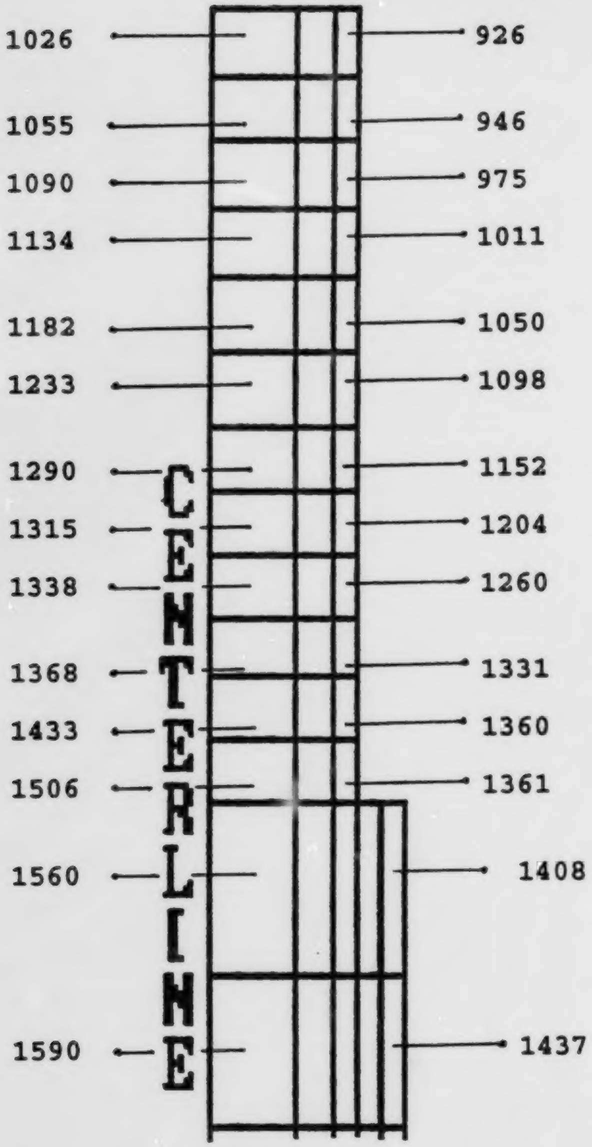


Figure 3. Temperature (K) Distribution for Lingan Boiler at 65% Load.

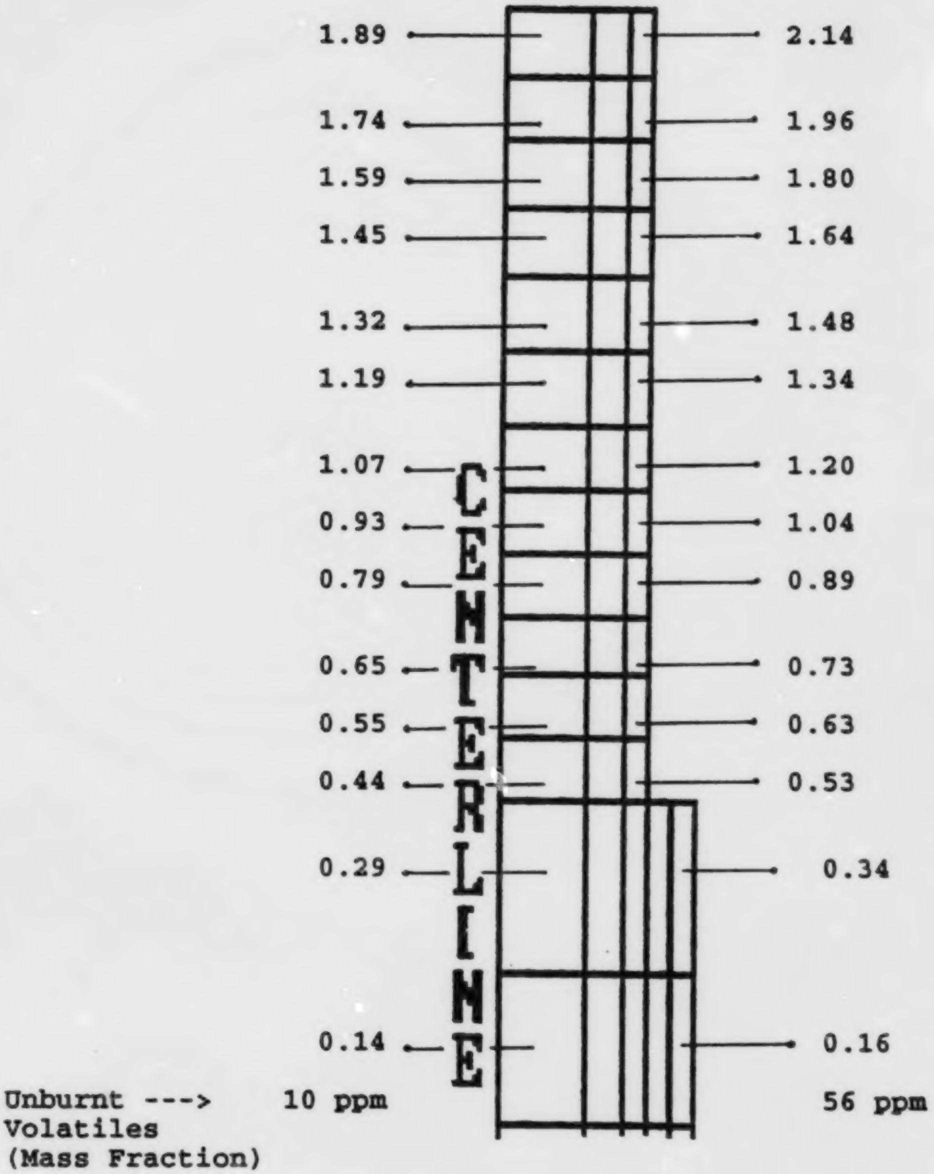


Figure 4. Cumulative Residence Times (s) Throughout Lingan Boiler (100% Load).

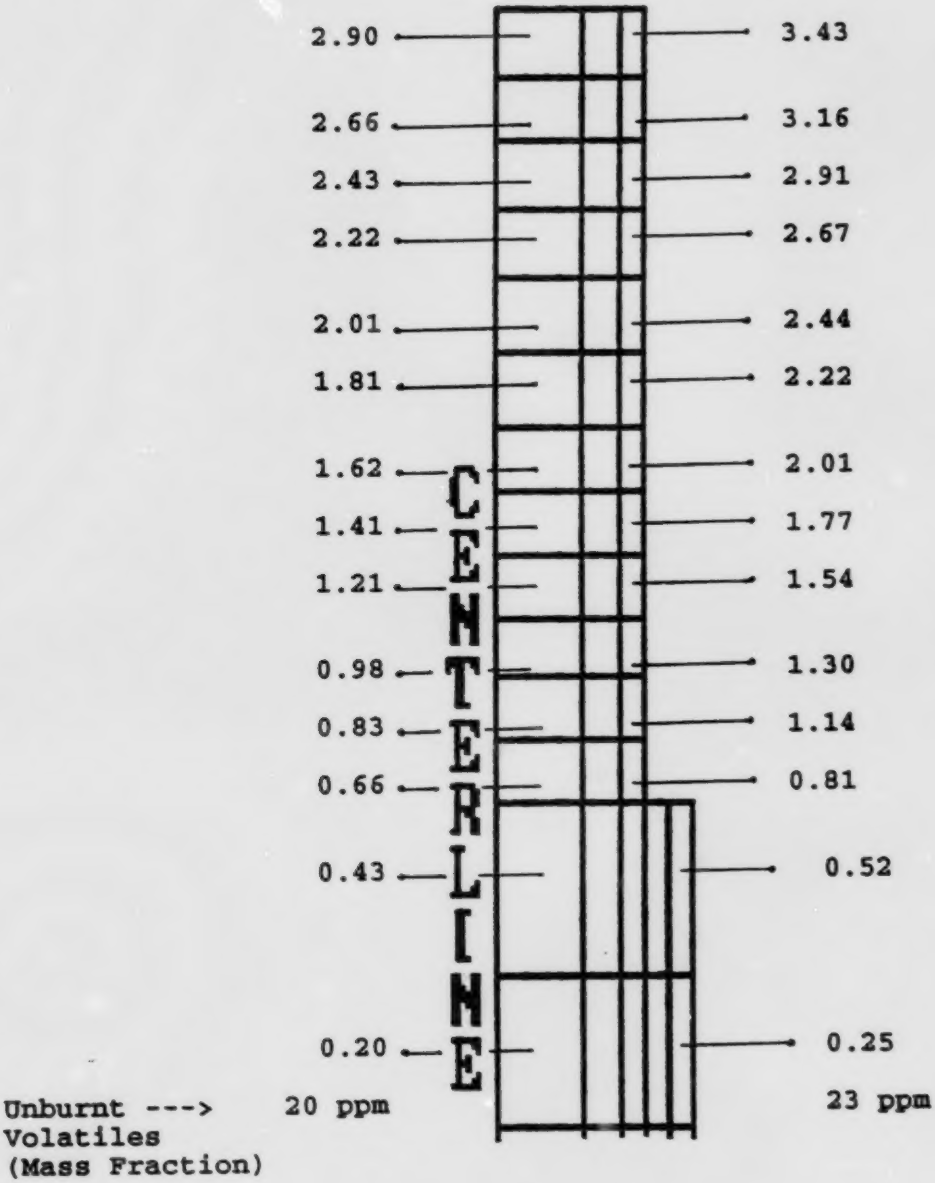


Figure 5. Cumulative Residence Times (s)
Throughout Lingan Boiler (65% Load).

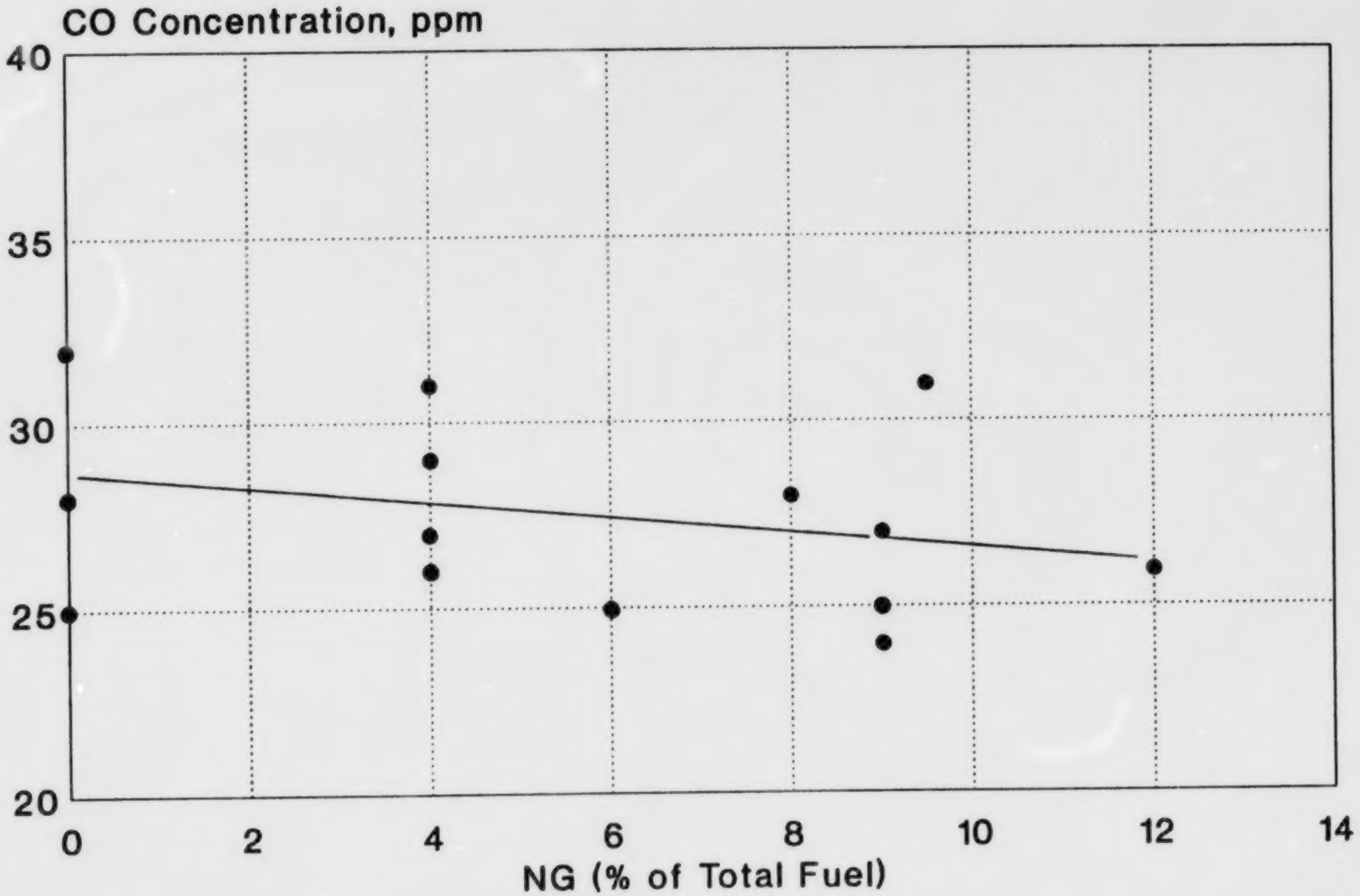


Figure 6. Effect of Natural Gas Load on Carbon Monoxide Concentration

APPENDIX 2.5
GEOTECHNICAL REPORT

TEST PIT INVESTIGATION

FEASIBILITY STUDY FOR PROPOSED METHANE GAS PIPELINE LINGAN MINE TO GENERATING STATION

LINGAN NOVA SCOTIA
PROJECT No. S539

PROJECT No. S539

REPORT

TO

FENCO SHAWINIGAN ENGINEERING (1985) LIMITED

ON

TEST PIT INVESTIGATION
FEASIBILITY STUDY FOR PROPOSED METHANE GAS PIPELINE
LINGAN MINE TO GENERATING STATION

LINGAN NOVA SCOTIA

Jacques, Whitford and Associates Limited
October 31, 1990

Jacques, Whitford and Associates Limited

Consulting Engineers
and Scientists

P.O. Box 1231
130 Charlotte Street
Sydney, Nova Scotia
B1P 6J9

Tel. 902 564 1855
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Site Investigations
Blasting Control
Materials, Mining
Hydrogeology
Earthworks
Foundations
Environmental Sciences
Rock Mechanics

Dartmouth, N.S.
Charlottetown, P.E.I
Saint John, N.B
Fredericton, N.B
Bathurst, N.B
Moncton, N.B
St. John's, Nfld
Corner Brook, Nfld
Hull, P.Q
Ottawa, Ont

October 31, 1990
Project No. S539

Fenco Shawinigan Engineering (1985) Limited
Suite 200, Park Lane Terraces
5657 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

Attention: Mr. J. Shanahan, Project Manager

RE: GEOTECHNICAL STUDY, LINGAN METHANE PIPELINE
FEASIBILITY STUDY, LINGAN, NOVA SCOTIA

Dear Sirs:

This letter reports the results of a preliminary geotechnical study carried out to specifically evaluate the potential northern route of the proposed pipeline to extend from the Lingan Mine Fan House to the Lingan Generating Station in Lingan, Nova Scotia. It is understood that four (4) routes have been considered for the proposed pipeline and that the central and northern routes have been evaluated for various reasons as being the two most appropriate for detailed consideration. A walkover survey of the central route was carried out by the writer together with members of your staff earlier this year. On the basis of the walkover survey, it was evident that terrain difficulties together with potential snow drifting effects on the adjacent rail line made the central alignment less desireable in comparison to the northern route. Consequently, it was agreed that investigation of the northern route alone was required at this time.

The writer carried out a visual reconnaissance of the proposed northern route on October 4, 1990. Much of the route will pass through virgin woodlands and brush. Based on our previous knowledge of the general area, it is anticipated that this portion of the alignment will be underlain by glacial sandy silt till in turn underlain at relatively shallow depth by sandstone bedrock of the Sydney Mines formation of the Morien group.

As discussed in our meeting of October 5, 1990, the area between the existing Lingan Mine Fan House and the area around the Lingan Phalen Mine Fan, was the section which we felt required some detailed field investigation in the form of test pits at the feasibility stage. The purpose of the field work was to verify the most appropriate route through this section and to investigate the presence of fills and/or organic deposits which may require a special type of foundation design or route alteration. Detailed geotechnical information in the area of a proposed methane gas exhaust stack and compressor building to be located to the immediate north of the Fan House was obtained in November of 1987 and is given in our Report No. S316 to you dated December 16, 1987.

1.0 PROCEDURE

The field work for this investigation was carried out on October 17, 1990. On this date a total of five (5) test pits were put down at the approximate locations shown on the attached Sketch No. S539-SK-1. The test pits were put down to depths of between 1.5 and 2.9 m below ground surface using a rubber tyred backhoe supplied locally. Representative samples of the subsoil encountered in selected test pits were obtained and the observed soil and water conditions in the test pits were logged. Following completion of the sampling and logging of each pit, each hole was fully backfilled.

2.0 SUBSURFACE CONDITIONS

The detailed stratigraphy encountered in each test pit is given on the Test Pit Records in the Appendix together with the results of laboratory testing. Following is a brief summary of the subsurface conditions encountered.

2.1 Fill

Test Pits 1, 2 and 3, put down inside the Lingan Mine storage yard encountered a layer of fill immediately below the paved surface of the yard. The fill is generally comprised of sandy clayey silt containing varying concentrations of gravel, shale and sandstone slabs with traces of wood. The fill layer was not fully penetrated in Test Pit 1 but was excavated to a depth of approximately 2.1 m.(Stockpiled material in the area of investigation made further excavation impossible). In Test Pits 2 and 3 the fill layer is 1.7 to 1.8 m thick.

Based on the rate of excavation by the backhoe and on visual assessment of the density of the excavated material, the fill layer is considered to be in a loose to compact state.

2.2 Brown Silt, Sand and Gravel

The fill layer in Test Pits 2 and 3 and a 150 mm thick topsoil layer in Test Pit 4 are underlain by a brown heterogeneous mixture of silt, sand and gravel containing some cobbles and occasional boulders. This deposit was not fully penetrated in Test Pits 2 and 3 but was excavated to a depth of 750 mm to 1.2 m. In Test Pit 4 this deposit is 1.7 m thick and is directly underlain by what is inferred to be sandstone bedrock.

The results of gradation analyses carried out on samples from this deposit are given on Figure 1 in the Appendix. Natural moisture contents in this deposit ranged between 12.7 and 17.5 percent.

Based on the rate of excavation by the backhoe and on tactile examination of the test pit sides this deposit is considered to be in a compact to dense state.

2.3 Organic Silt

Test Pit 5 was put down in the area to the immediate west of the fill embankment constructed for the Phalen Mine Fan House. Based on the results of the initial walkover of the line by the writer swampy conditions were identified in this area. Test Pit 5 was put down on the edge of the swamp as close as the backhoe was able to approach without getting stuck. Surface ponded water existed in this area and a two (2) foot thick layer of grey organic silt containing roots and swamp grass was encountered at surface. The organic silt is in a loose to very loose state. The organic silt layer is directly underlain by a deposit of compact to dense grey silty sand and gravel which was excavated to a depth of about 1 m.

3.0 DISCUSSION

As noted previously, the proposed northern route for the pipeline has been identified as that which appears most feasible at this stage. Based on the results of the walkover survey for the central portion of the northern route, we anticipate that the subsurface conditions will consist largely of dense glacial tills overlying sandstone bedrock at relatively shallow depth. Consequently, it should be possible to derive two basic foundation configurations, one for footings placed on the glacial till at 1.2 m depth and one for footings bearing directly on bedrock with suitable anchorage where required, that would be applicable to the entire central portion of the project. The footing configurations could be based on preliminary bearing values typically in the range of 190 kPa for till and 950 kPa on rock, to be confirmed at the detailed design stage by further geotechnical investigation.

In the area of the existing Lingan Mine Yard, the original proposed alignment for the northern route indicated an immediate crossing of the Lingan Highway essentially perpendicularly out from the Fan House location with the route then paralleling the Highway some 300 m before bearing off towards the Phalen Fan House location. Based on visual reconnaissance of this area, the writer suggested that terrain difficulties (a deep valley exists along the northern edge of the Lingan Highway immediately north of the Lingan Mine Yard), the presence of swamp conditions and the existing power line made this portion of the alignment difficult to construct. It was recommended that the initial portion of the pipeline be maintained along the northern boundary/fenceline of the Yard itself, as proposed for the Central Route, and that the Lingan Highway crossing be effected in the approximate area of Test Pit 3. The primary concern with this portion of the route would then be the competency of the soils along this section since it was known that filling had been carried out over this entire area. The results of the test pits from our study in 1987 and the current study indicate that the fills along the alignment are generally in the order of 2 m or less in thickness and the composition of the fill is such that, with some over excavation and recompaction , the material could support the anticipated relatively light loading without significant settlements developing. The underlying natural silt, sand and gravel till is suitable for spread footing support of the proposed pipeline system.

In the area of the Phalen Mine Fan House, the principal concerns with foundation support of the pipeline are the presence of the swamp area to the immediate west of the Fan House fill embankment coupled with the drop in terrain elevation and the condition of the fill itself around the fan house. The swamp condition appears to be relatively shallow and, although some provision for water flow control will be required, the underlying compact to dense sand and gravel deposit will be adequate for support of the foundations. Some high foundation supports with associated high eccentric edge pressures may be required in this area. The fill at each footing location around the Phalen Fan House will have to be investigated individually at the detailed design stage to determine the variation in conditions. Based on our previous experience in this area, it is known that the fill conditions can be highly variable.

Detailed investigation of the area around the Lingan Generating Station itself has not been carried out. However existing geotechnical data in this area indicates that suitable foundation conditions will exist. Accurate assessment of foundation conditions at the specific footing locations will be necessary at a later date particularly where filling may have been carried out.

As discussed with you during our meeting of October 5, 1990, the observation posts formerly located adjacent to the Lingan Mine Yard may have incorporated underground tunnels. That we are aware of, no records of the these tunnels exist or their locations, if in fact they do exist. Some provision may be required at the tender construction stage for treatment or relocation of footings in these areas in the event that tunnel obstructions are encountered.

In summary, no subsurface conditions were encountered during this study that would affect the overall feasibility of the project. The fill conditions in the area of the Lingan Yard and the swampy conditions adjacent to the Phalen Fan House location are generally surficial in nature and, with some minor special field preparation can be accommodated.

We trust that report is sufficient for your present requirements. If you have any questions regarding this letter or we can be of further service to you on this project, please contact us at your convenience.

Respectfully;
JACQUES, WHITFORD AND ASSOCIATES LIMITED

Paul A Graham

Paul A. Graham, P. Eng.

APPENDIX

SYMBOLS AND TERMS USED ON THE BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Behavioural properties (i.e. plasticity, permeability) take precedence over particle gradation in describing soils.

Terminology describing soil structure:

Desiccated	-	having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	-	having cracks, and hence a blocky structure
Varved	-	composed of regular alternating layers of silt and clay
Stratified	-	composed of alternating layers of different soil types, e.g. silt and sand or silt and clay
Well Graded	-	having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Uniformly Graded	-	predominantly of one grain size.

Terminology used for describing soil strata based upon the proportion of individual particle sizes present:

Trace, or occasional	less than 10%
Some	10-20%
Adjective (e.g. silty or sandy)	20-35%
And (e.g. silt and sand)	35-50%

The standard terminology to describe cohesionless soils includes the relative density, as determined by laboratory test or by the Standard Penetration Test 'N' - value: the number of blows of 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler one foot (305mm) into the soil.

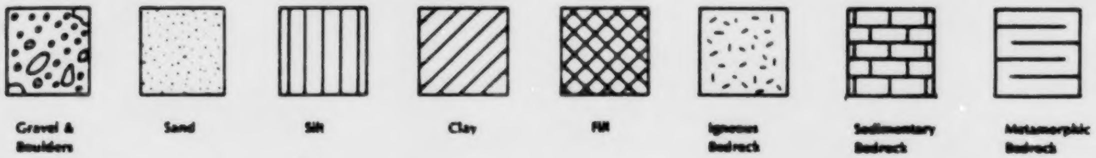
Relative Density	'N' Value	Relative Density %
Very Loose	<4	<15
Loose	4-10	15-35
Compact	10-30	35-65
Dense	30-50	65-85
Very Dense	>50	>85

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests, or occasionally by standard penetration tests.

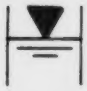
Consistency	Undrained Shear Strength		'N' Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25-0.5	12.5-25	2-4
Firm	0.5-1.0	25-50	4-8
Stiff	1.0-2.0	50-100	8-15
Very Stiff	2.0-4.0	100-200	15-30
Hard	>4.0	>200	>30

SYMBOLS AND TERMS CONTINUED

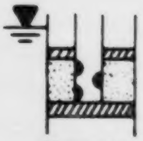
STRATA PLOT



WATER LEVEL MEASUREMENT



Borehole or Standpipe



Piezometer

SAMPLES

SS....	Split spoon sample (obtained by performing the standard penetration test)
ST....	Shelby tube or thin wall tube
PS....	Piston sample
BS....	Bulk sample
WS....	Wash sample
RC....	Rock core AXT, BXL, etc.... Rock core samples obtained with the use of standard diamond drilling bits.

OTHER TESTS

G.....	Specific gravity
H.....	Hydrometer analysis
S.....	Sieve analysis
γ....	Unit weight
C.....	Consolidation
CD....	Consolidated drained triaxial
CU....	Consolidated undrained triaxial with pore pressure measurements
UU....	Unconsolidated undrained triaxial
DS....	Direct shear
P.....	Field permeability

ROCK DESCRIPTION

The description of bedrock is based on the rock quality designation (RQD).

The classification is based on a modified core recovery percentage in which all pieces of sound core over 100mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. In most cases RQD is run on NXL core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from normal insitu fractures.

RQD	ROCK QUALITY
90-100	Excellent, intact, very sound
75-90	Good, massive, moderately jointed or sound
50-75	Fair, blocky and seamy, fractured
25-50	Poor, shattered and very seamy or blocky, severely fractured
0-25	Very poor, crushed, very severely fractured.

TEST PIT RECORD

TEST PIT No. 1

CLIENT Fenco Shawinigan Engineering Ltd.

PROJECT No. S539

LOCATION Proposed Lingan Methane Pipeline, Lingan, N.S.

DATES: DUG October 17, 1990 WATER LEVEL October 17, 1990 DATUM

DEPTH (FT.)	DEPTH (M)	ELEVATION	SOIL DESCRIPTION	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	OTHER TESTS	UNDRAINED SHEAR STRENGTH – WATER CONTENT & ATTERBERG LIMITS Wp W WL 10 20 30 40 50 60 70 80 90
	0		ASPHALT					
	1 2		Compact Grey and Brown Sandy Clayey Silt, Some Gravel, Shale and Sandstone Slabs Throughout Trace Wood FILL					
	3		End of Test Pit					

TEST PIT RECORD

TEST PIT No. 2

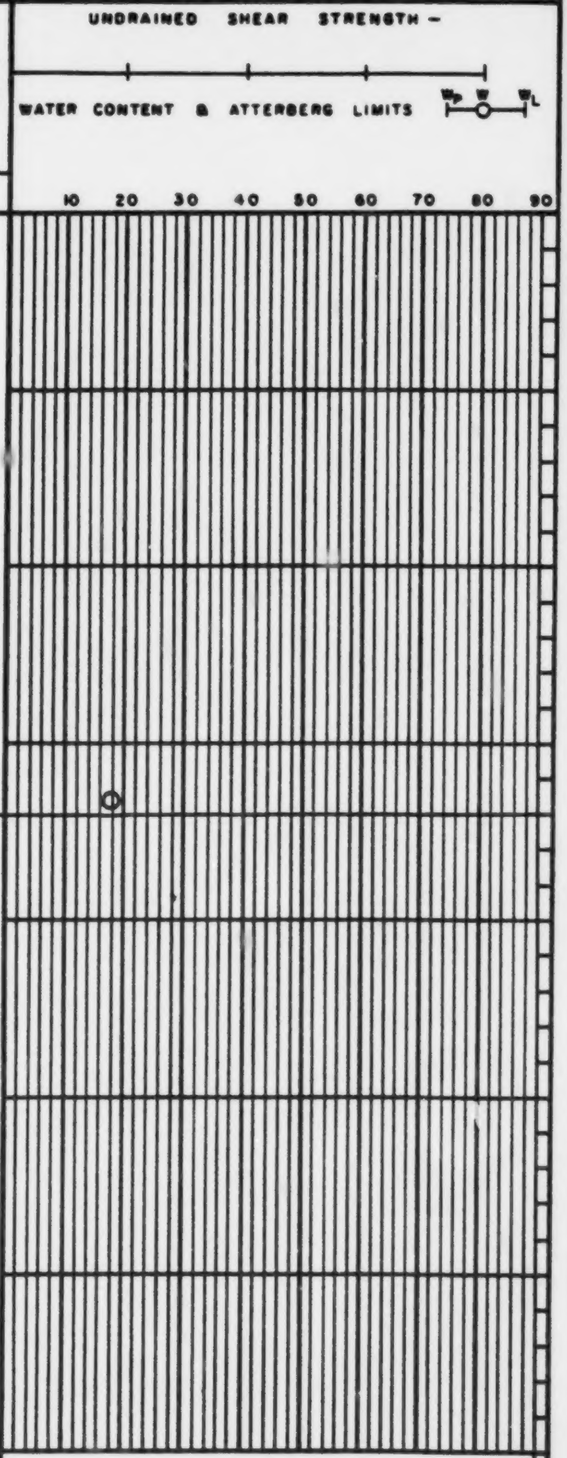
CLIENT Fenco Shawinigan Engineering Ltd.

PROJECT No. S539

LOCATION Proposed Lingan Methane Pipeline, Lingan, N.S.

DATES: DUG October 17, 1990 WATER LEVEL October 17, 1990 DATUM

DEPTH (FT.)	DEPTH (M)	ELEVATION	SOIL DESCRIPTION	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	OTHER TESTS
	0 – 1.8		Compact to Loose Grey Brown Clayey Sandy Silt Some Gravel, Some Cobbles & Boulders Throughout, Trace Wood FILL				
	1.8 – 2.6		Compact Rust Brown SAND, SILT AND GRAVEL		BS	1	S
	2.6		End of Test Pit				



TEST PIT RECORD

TEST PIT No. 3

CLIENT Fenco Shawinigan Engineering Ltd.

PROJECT No. S539

LOCATION Proposed Lingan Methane Pipeline, Lingan, N.S.

DATES: DUG October 17, 1990

WATER LEVEL OCtober 17, 1990

DATUM

DEPTH (FT.)	DEPTH (M)	ELEVATION	SOIL DESCRIPTION	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	OTHER TESTS	UNDRAINED SHEAR STRENGTH – WATER CONTENT & ATTERBERG LIMITS W_P W W_L 10 20 30 40 50 60 70 80 90
	0		Compact Grey Brown Silty Sand Some Gravel, Cobbles and Boulders Trace Clay FILL					
	1							
	2		Compact To Dense Brown to Grey Brown SILT, SAND & GRAVEL Cccasional Cobble		BS	1	S	○
	3		End of Test Pit					

TEST PIT RECORD

TEST PIT No. 4

CLIENT Fenco Shawinigan Engineering Ltd.

PROJECT No. S539

LOCATION Proposed Lingan Methane Pipeline, Lingan, N.S.

DATES: DUG October 17, 1990 WATER LEVEL October 17, 1990 DATUM

DEPTH (FT.)	DEPTH (M)	ELEVATION	SOIL DESCRIPTION	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	OTHER TESTS	UNDRAINED SHEAR STRENGTH – / WATER CONTENT & ATTERBERG LIMITS W_P W W_L (10 20 30 40 50 60 70 80 90)
	0		Brown Silty Sand TOPSOIL AND ROOTS					
	1		Dense Brown SILT, SAND AND GRAVEL					
	2		End of Test Pit on Probable Sandstone Bedrock					
	3							

TEST PIT RECORD

TEST PIT No. 5

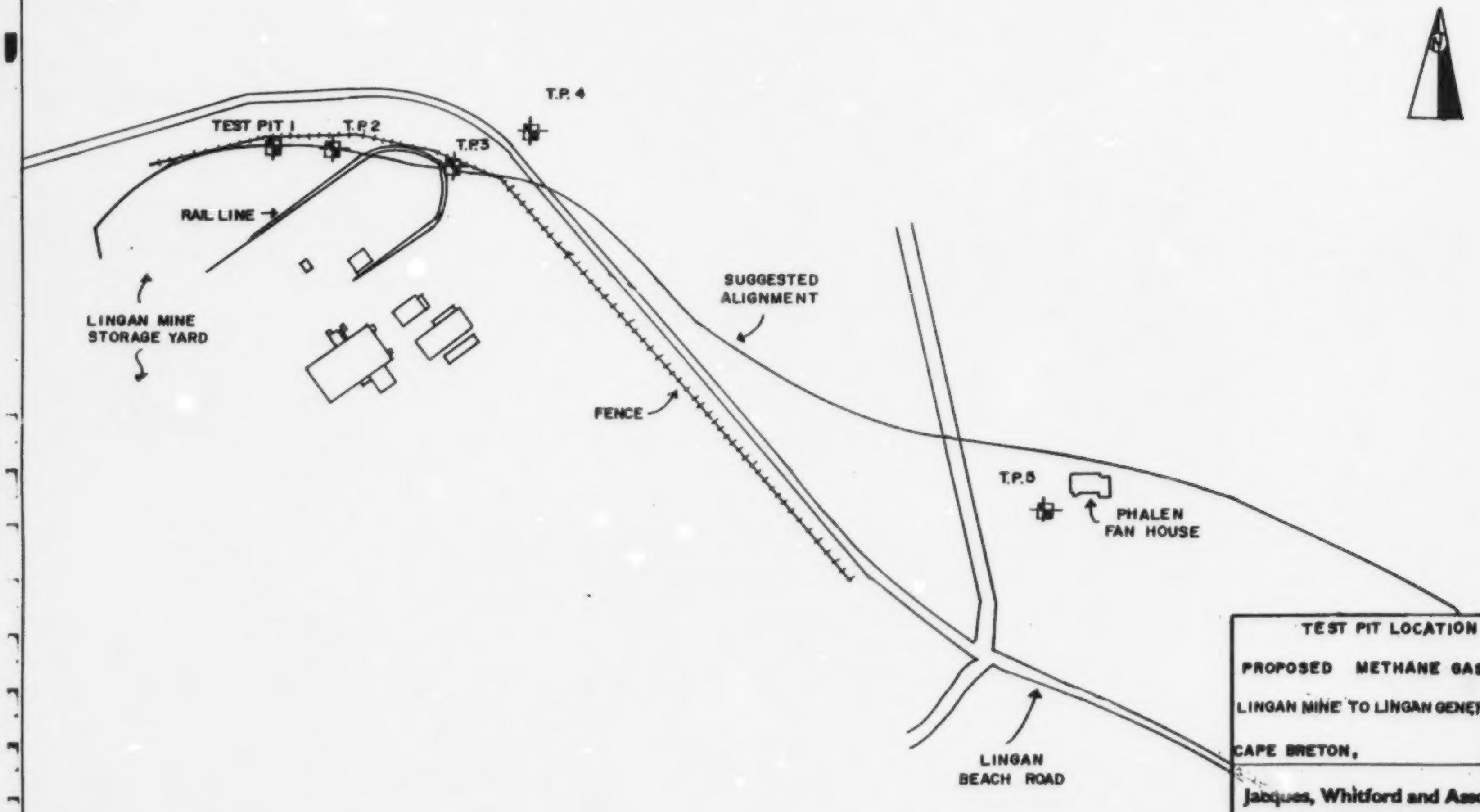
CLIENT Fenco Shawinigan Engineering Ltd.

PROJECT No. S539

LOCATION Proposed Lingan Methane Pipeline, Lingan, N.S.

DATES: DUG October 17, 1990 WATER LEVEL October 17, 1990 DATUM

DEPTH (FT.)	DEPTH (M)	ELEVATION	SOIL DESCRIPTION	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	OTHER TESTS	UNDRAINED SHEAR STRENGTH – WATER CONTENT & ATTERBERG LIMITS Wp W WL
	0			▼				10 20 30 40 50 60 70 80 90
			Soft Grey ORGANIC SILT Some Sand and Gravel					
	1		Compact to Dense Grey Brown SILTY SAND AND GRAVEL Trace Clay					
			End of Test Pit					
	2							



TEST PIT LOCATION PLAN

PROPOSED METHANE GAS PIPELINE

LINGAN MINE TO LINGAN GENERATING STATION

CAPE BRETON, NOVA SCOTIA

Jacques, Whitford and Associates Limited
CONSULTING ENGINEERS

DATE: 01/11/90
SCALE: 1:250
DRAWN BY: A M K

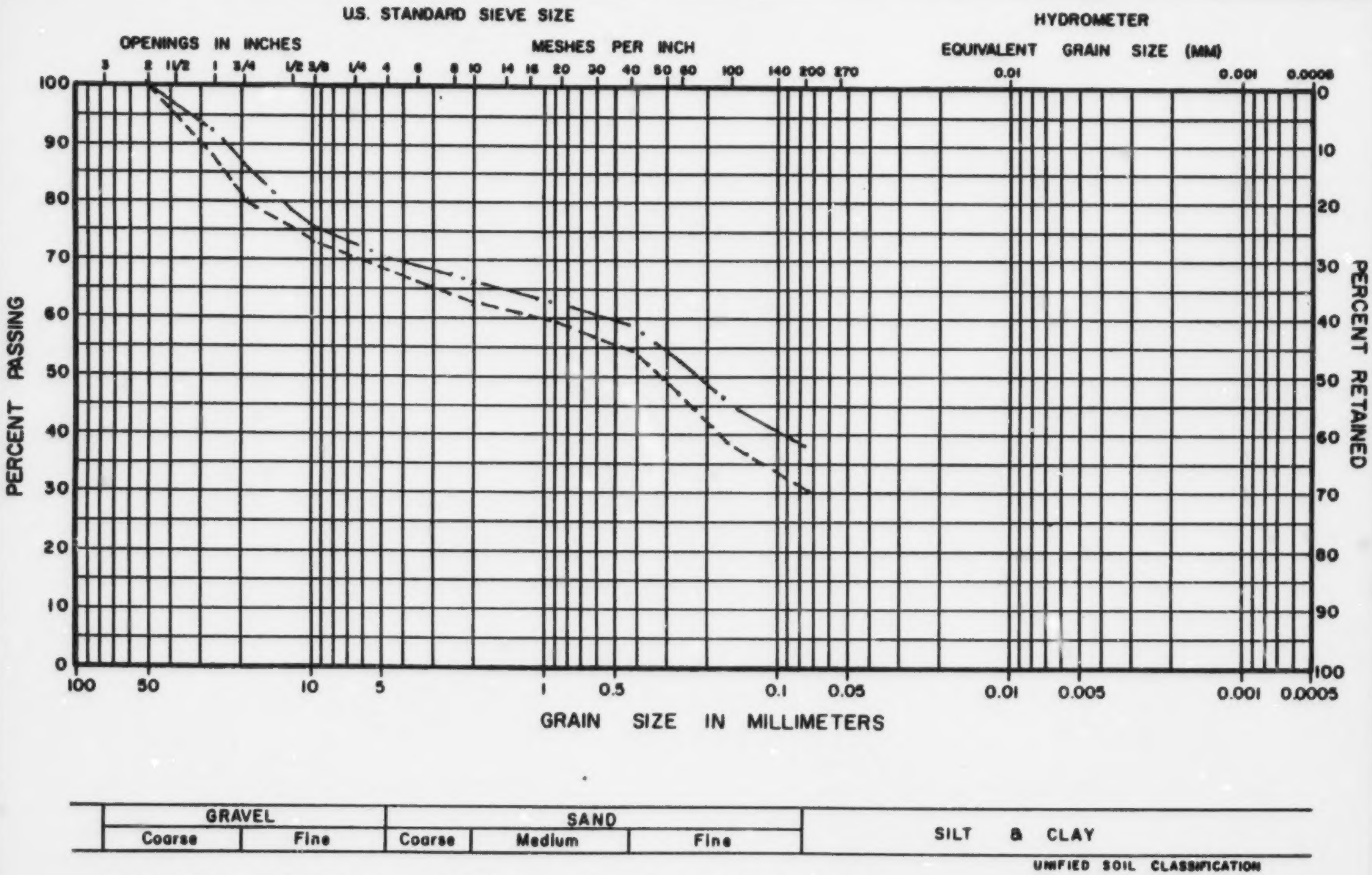
APPROVED BY: Paul A. Gealow

DRAWING NO.: S539-SK-1

224 3/84

GRAIN SIZE DISTRIBUTION

APPENDIX
FIGURE 1
PROJECT S339



	BOREHOLE	TESTPIT	SAMPLE	DEPTH (m)	DESCRIPTION
— — — —		2	1	2.49-2.59	Brown SAND, SILT AND GRAVEL
—·—		3	1	2.29-2.44	Brown, SAND, SILT AND GRAVEL

APPENDIX 2.6
T.U.N.S. REPORT

Mr. John Shanahan
Fenco Shawinigan Engineering (1985) Limited
Suite 200, Park Lane Terraces
5657 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

December 10, 1990

Dear Mr. Shanahan:

Enclosed is a written response to your request for our opinion on the hazard caused by the co-existence of methane and coal dust. This note has been prepared in consultation with your study-team personnel with regard to the use of mine return air in coal pulverizers.

Please let us know if you have any questions on the contents of the note, or would like to discuss any further details.

Sincerely,

Paul Amyotte

Paul Amyotte, Ph.D., P.Eng.

Mike Pegg, Ph.D.

Department of Chemical Engineering
Technical University of Nova Scotia
P.O. Box 1000
Halifax, Nova Scotia
B3J 2X4

Increased Hazard Due to Co-Existence of Methane and Coal Dust

Paul Amyotte, P.Eng.
Michael Pegg
Department of Chemical Engineering
Technical University of Nova Scotia
P.O. Box 1000
Halifax, Nova Scotia
B3J 2X4

December 10, 1990

Introduction

The purpose of this note is to comment on the effects of methane admixture on the explosibility of coal dust. Coal dust alone represents a significant explosion hazard; this hazard is magnified by the addition of methane to the oxidizing atmosphere. The increase in explosion hazard occurs in a number of areas: higher explosion pressures and rates of pressure rise, leaner concentrations of coal dust at which the peak explosion pressures and rates of pressure rise occur, lower lean flammability limits, increased amounts of inert material for explosion suppression, and enhanced ignitability of the explosive mixture.

Scope

The points discussed here have general applicability to any situation where methane and coal dust are found together. The comments are therefore pertinent to the proposed use of mine return air (MRA) in coal pulverizers; MRA typically contains 0.8 - 1 volume % methane.

Basis for Comments

The comments contained in this note are based on a substantial amount of experimental work conducted by the authors, in addition to a review of the dust explosion literature. The experimental work involved testing various aspects of the explosibility of coal dust generated from Cape Breton Development Corporation (CBDC) coals (from the Prince, Lingan and Phalen mines), at methane concentrations of 0, 1 and 2 % by volume. Pertinent references are the following:

1. Amyotte, P.R., Pegg, M.J. and Sun, Y.H., *Examination of the Explosion Characteristics of Methane/ Coal Dust/Dolomite/ Air Mixtures*, Halifax, Nova Scotia (January, 1990) [Report of work done under DSS Contract 23440-8-9077/01-SQ].

2. Amyotte, P.R., Pegg, M.J. and Sun, Y.H., *Examination of the Ignitability Characteristics of Coal Dust/Air and Methane/Coal Dust Air Mixtures*, Halifax, Nova Scotia (in preparation) [Report of work done under DSS Contract 23440-9-9200/01-SS].

3. Amyotte, P.R., Mintz, K.J., Pegg, M.J. and Sun, Y.H., *Examination of the Explosion Effects of Methane/Coal Dust/Air Mixtures*, Spring Technical Meeting of Combustion Institute (Canadian Section), University of Toronto, Toronto, Ontario (May 31 - June 2, 1989), pp. 20-22.

4. Amyotte, P.R., Mintz, K.J., Pegg, M.J. and Sun, Y.H., *Dust Explosibility Characteristics of Three Nova Scotia Coals*, Spring Technical Meeting of Combustion Institute (Canadian Section), Banff, Alberta (April 29 - May 2, 1990), pp. 230-234.

5. Amyotte, P.R., Mintz, K.J., Pegg, M.J. and Sun, Y.H., *Dolomite Inerting Requirements of Three Nova Scotia Coals*, Spring Technical Meeting of Combustion Institute (Canadian Section), Banff, Alberta (April 29 - May 2, 1990), pp. 256-260.

6. Amyotte, P.R. and Pegg, M.J., *Coal Dust Explosions: Occurrence and Prevention*, 25th Annual Fall Meeting of Mining Society of Nova Scotia, Sydney, Nova Scotia (October 27, 1990).

7. Pegg, M.J., Amyotte, P.R. and Sun, Y.H., *Hybrid-Mixture Explosions*, 40th Canadian Chemical Engineering Conference, Dalhousie University, Halifax, Nova Scotia (July 15 - 20, 1990), p. 157.

8. Amyotte, P.R., Mintz, K.J., Pegg, M.J., Sun, Y.H. and Wilkie, K.I., *Effects of Methane Admixture, Particle Size and Volatile Content on the Dolomite Inerting Requirements of Coal Dust*, Journal of Hazardous Materials (in press).

9. Amyotte, P.R., Mintz, K.J., Pegg, M.J., Sun, Y.H. and Wilkie, K.I., *Laboratory Investigation of the Dust Explosibility Characteristics of Three Nova Scotia Coals*, Journal of Loss Prevention in the Process Industries (in press).

Coal Dust Explosion Hazard

The explosion hazard due to coal dust alone is well established and documented. In closed vessel explosibility testing, one typically observes the following for coal dust:

1. A rise to a maximum and then levelling off of both the maximum explosion pressure, P_{max}, and the maximum rate of pressure rise, $(dP/dt)_{max}$, as dust concentration is increased. P_{max} and $(dP/dt)_{max}$ are used as indicators of explosion severity or violence because they relate to the pressure effects experienced following ignition, in terms of both their final magnitude and the speed with which they occur.

2. The optimum dust concentration occurring at three to four times the stoichiometric concentration of the coal. Optimum dust concentration refers to the dust concentration at which the peak values of P_{max} and $(dP/dt)_{max}$ are recorded; a typical value for CBDC coals is ~ 0.5 kg/m^3.

3. The occurrence of a lean flammibility limit (also called minimum explosible concentration). A typical value for CBDC coals is ~ 0.1 kg/m^3.

4. The absence of a rich flammability limit. There is some debate on this point. Some researchers claim there is no rich limit for coal dust; others say there is, we simply cannot measure it because of the difficulty of uniformly dispersing large quantities of coal dust. With a relatively low lean limit and a high rich limit (if one exists), it is wise to assume that any coal dust/air mixture is explosible unless there is compelling evidence to the contrary.

Methane Admixture

The previous paragraph outlines several features of the hazard due to coal dust/oxidant mixtures. The addition of methane, even in concentrations which by themselves are *nonflammable*, to a coal dust/air suspension can significantly increase the explosion hazard over that for a similar dust cloud with no methane present. The formation of such a hybrid mixture (flammable gas and combustible dust) is avoided in industry (witness the use of ventilation air in coal mines to prevent the formation of both flammable and nonflammable methane accumulations). Effects of methane admixture to coal dust, in terms of a heightened explosibility, are as follows:

1. For coal dust concentrations less than the optimum concentration, the maximum explosion pressure is somewhat increased by methane admixture; in tests conducted by the authors with CBDC coals near the lean flammability limit, P_{max} was at times doubled by the addition of 1% methane by volume. The influence of methane admixture becomes less significant as the coal dust concentration approaches the optimum concentration, until at high dust loadings (greater than optimum), methane has little, if any, effect on the maximum explosion pressure.

2. The maximum rate of pressure rise undergoes a significant increase with methane addition at all coal dust concentrations. The burning velocity of the mixture and hence the flame speed increase accordingly.
Methane admixture has a more significant effect on $(dP/dt)_{max}$ than on P_{max}, with this effect being apparent over a wider range of dust concentrations for $(dP/dt)_{max}$ than for P_{max}.

3. With methane addition, the peak values of P_{max} and $(dP/dt)_{max}$ occur at dust concentrations which are less than those for coal dust alone. In tests conducted by the authors with CBDC coals, a typical value was a decrease in coal dust concentration of ~ 0.1 kg/m^3 at the 1 % methane level. In these tests, the shift in optimum dust concentration was more apparent at 2 % methane than at 1 %.

4. The peak values of $(dP/dt)_{max}$ for coal dust alone are exceeded by methane/coal dust mixtures at leaner dust concentrations.
The combustion of a volatile dust is usually viewed as a stepwise process in which devolatilization occurs followed by burning of gaseous volatiles, with the peak value of maximum rate of pressure rise corresponding to the burning of a near-stoichiometric concentration of these volatiles. One of the primary effects of methane admixture, therefore, is to enable the fuel/air mixture to attain a stoichiometric or near-stoichiometric concentration of combustible volatiles at lower dust concentrations.

5. Methane addition has a significant effect on the lean flammability limit of coal dust; in the presence of small amounts of methane, less coal dust is required to initiate an explosion for a given ignition energy. This decrease in the lean limit can be predicted by Le Chatelier's law, which weights the lean limit for each of the two components (methane and coal dust) according to the percentage of each in the hybrid mixture.

6. It is well-established that an effect of methane addition is to increase the amount of inert material required to suppress an explosion. For example, in the coal mining industry, the presence of methane necessitates the use of additional rock dust (typically limestone or dolomite) for inerting. A rule of thumb often followed is 5 % more rock dust for each 1 % by volume methane; at the high levels of rock dust required to inert coal dust alone, an additional 5 % is a significant mass of inert material. A general comment, therefore, is that inerting levels must be based on the actual hazard; inerting requirements for a combustible dust alone are inadequate if the dust coexists with a flammable gas.

7. The co-existence of methane with coal dust enhances the ignitability of the coal dust. In other words, ignition of a given coal dust concentration is attainable with lower energies when a small percentage of methane is present. Energies which may be inadequate for ignition of a coal dust/air suspension, or which may lead to only limited explosion pressures and rates of pressure rise, have the potential to initiate a hybrid-mixture explosion.

There are two additional points on methane admixture worth mentioning, although they are somewhat speculative:

What happens to the rich flammability limit (if there is one) with methane addition? It is likely that a rich limit would be extended to higher dust concentrations, just as the lean limit is extended to lower dust concentrations.

Is it possible for a methane accumulation (which is flammable by itself) to occur somewhere in the system? If so, the potential for a *primary* explosion of methane followed by a *secondary* explosion of coal dust must be considered. This is the typical sequence of events in a full-scale coal mine explosion.

Summary

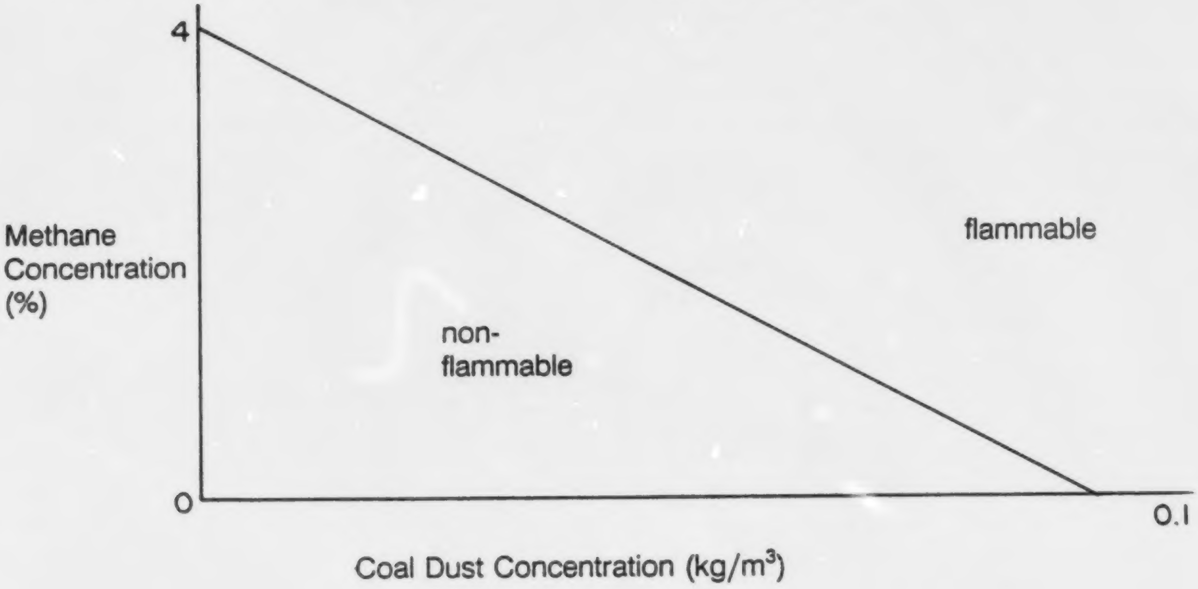
In this note, we have outlined ways in which the explosion hazard associated with coal dust is increased when methane is added to the oxidizing atmosphere. The following three points are central to the discussion:

1. There is already a hazard which exists when coal dust is present. With methane admixture, we are now talking about a magnification of this existing hazard, not the creation of a problem which did not exist in some form already.

2. The increase in hazard can be brought about by the addition of small percentages of methane which by themselves are nonflammable (i.e. below the lean flammability limit for methane).

3. The increase in hazard occurs in several areas, not just one. Consideration must be given to safety implications other than those relating to the expected pressure effects following ignition and the dust concentrations at which these effects occur. Extension of the lean flammability limit, increased inerting requirements, and enhanced ignitability must also be considered.

As explained in the letter from Dr. Amyotte and Dr. Pegg, (see previous letter), the addition of methane to the air/coal dust mixture in the mills has the effect of reducing the lean flammability limits; that is, the amount of coal dust required for a flammable (explosive) mixture decreases as methane is added. This is illustrated in the following figure (taken from: "Examination of the Explosion Characteristics of Methane/Coal Dust/Dolomite/Air Mixtures", by Amyotte, Pegg and Sun, 1990 January).



The following letter by J.C. Campbell, CBDC, explains that under normal operating conditions the concentration of methane in the mills generated from comminution of the coal is about 0.03 percent. Thus, in light of the above figure, addition of a methane-enhanced primary air to the mills would represent a large increase in methane concentration (from 0.03 to perhaps 0.8 percent), and would significantly increase the hazard by reducing the lower flammability limit.

APPENDIX 2.7

BOILER MANUFACTURERS REPORT & CORRESPONDENCE

AN INTERIM REPORT

ON THE

Lingan/Phalen Mine Methane Utilization Study

For

Nova Scotia Department of Mines and Energy

PREPARED BY:

ABB COMBUSTION ENGINEERING SERVICES CANADA
99 BANK ST., SUITE 501
OTTAWA, ONTARIO

STUDY NO. S903013

DECEMBER 1990

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1.0 INTRODUCTION

The report presents the results of ABB-CE Services' evaluation and its recommendation regarding the various separate primary air flue gas, flue gas plus air coal drying transport schemes which have been suggested as possible methods of safely separating the methane gas and combustion air stream from the pulverized fuel systems on these units.

Based on its evaluation, it is ABB-CE Services' opinion that the segregation of the existing Ljungstrom air heaters into separate primary and secondary compartments, or the installation of a separate primary tubular air heater, as outlined in Option "A" below, would afford the most effective methods of achieving the client's objectives. The modifications associated with each of these alternatives, represent proven, reliable design concepts which are typical of those employed on numerous successfully operating boiler installations, and which would assure the safe, reliable and efficient future operation of these units.

A summary of the scope of changes proposed for each of these two alternatives, as well as ABB-CE Services' observations and comments regarding the other suggested modifications are outlined below (Budgetary pricing and construction scheduling for the proposed alternatives will be forwarded under separate cover.):

2.0 OPTION A - SEGREGATION OF THE PRIMARY AND SECONDARY AIR STREAMS

2.1 Splitting of the Air Side of the Existing Ljungstrom Air Heater

This alternative consists of converting the existing Ljungstrom air heaters to quadsector or trisector configurations. With either of these arrangements, the combustion air side of both existing heaters would be modified, by means of new sector plates, seals, etc. to provide totally separate primary and secondary air heater chambers. Total segregation of the balance of the respective air systems would be accomplished by means of new ducting and primary air (P.A.) fans. Following this modification, M.R.A. would be directed exclusively to the secondary side of the system and uncontaminated, primary air to the mills would be assured by maintaining positive primary to secondary air pressure differential at the heater outlet.

The scope and arrangement of the new materials and equipment and modifications to existing equipment required with either the quadsector or trisector versions of this alternative would be very similar. A conceptual arrangement of the trisector scheme is presented in the attached copy of proposal sketch G-MMS-587-01. A detailed assessment of the modifications required to convert the existing Ljungstrom heaters to future quadsector or trisector operation will be provided under separate cover. In addition to the Ljungstrom air heater modifications described above, the scope of this modification would include the following:

- Two new primary air fans complete with motor drives. Fan and drive foundations are not included in the scope of this proposal and would be the client's responsibility.

- New primary air ducting, complete with all necessary expansion joints, dampers, access doors, supports (from the client's structural steel) and insulation (hot air ducting only). The terminals of supply for the proposed primary air ducting system will be the outlet of the new P.A. fans, the inlets and outlets of the new primary air compartments on the modified Ljungstrom air heaters and connections on the existing vertical primary air ducts upstream of the existing venturis.

- New secondary air ducting, complete with new expansion joints, dampers, steam coil air preheaters, supports (from the client's structural steel) and insulation (hot air ducting only). Terminals of supply for the proposed ducting would be at the existing F.D. outlet expansion joints, the inlet and outlet of the new secondary air compartments on the modified Ljungstrom air heaters and connections to the existing horizontal main hot air supply duct. Existing hot and cold air cross-over ducts would be reused with this proposal.

- The scope of this proposal does not include any damper actuators, controls, instrumentation, foundations or modifications to the client's existing platforms and structures required to accommodate the new primary or modified secondary air systems.

No appreciable change in performance or efficiency is anticipated for future operation of subject units following the modifications outlined above. However, due to the reduction in the free area of the secondary air side of the modified Ljungstrom heaters, high air side resistance could limit the ability to achieve maximum boiler load on auxiliary fuel with only the secondary air system in service. The installation of appropriate by-pass ducts, isolation and by-pass dampers would alleviate this potential problem by allowing the use of primary air to supplement the secondary air flow. These by-pass ducts, isolation and by-pass dampers are not included in the scope of this proposal.

2.2 Separate Tubular Air Heater

This alternative provides for the total separation of the primary and secondary air streams to the unit and would, therefore, eliminate any possibility of methane gas contaminating the air to the pulverizers. With this scheme, new primary air fans would provide the drying and conveying requirements of the existing pulverizers via a new tubular air heater and ducting. The scope and arrangement of the new materials and equipment and modifications to existing equipment associated with this alternative would be as illustrated on the attached copy of proposal sketch G-MMS-587-02 and as detailed in the following description:

- Two new primary air fans complete with new motor drives. Fan and drive foundations are not included in the scope of this proposal and would be the client's responsibility.

- New primary air ducting complete with all necessary expansion joints, dampers, access doors, supports (from the client's structural steel) and insulation (hot air ducting only) commencing at the outlet of the new P.A. fans and terminating at connections to the existing pulverizer hot air inlet ducts.

- New flue gas ducting complete with all necessary expansion joints dampers, access doors,insulation and supports (from the client's structural steel). The proposed ducting will commence at connections centered on the top of each of the two existing horizontal gas supply ducts to the existing Ljungstrom air heaters and terminate at connections centered on the top of each of the two existing flue gas ducts to the precipitator chambers, downstream of the Ljungstrom air heater gas outlets.

- One new primary tubular air heater. The proposed heater will employ horizontal, in line tubes and vertical tube sheets arranged for gas flow over and air flows through the tubes. Tube banks will be arranged to facilitate access and cleanability and sufficient new rotary sootblowers will be provided to assure optimum availability and performance of the heater surfaces under all operating conditions. New sootblower piping, from connections on the existing sootblower steam piping system, are also included with this proposal.

  The proposed heater will be furnished complete with all necessary casings, doors, integral ductwork, insulation and hanger supports (from the client's structural steel). Terminal of supply for the proposed heater will be at the ash hopper outlet flange.

- Modifications to the existing Ljungstrom heaters, in the form of double radial seals or double radial seals plus axial seals, that would improve sealing and reduce air leakage are included with this proposal. Anticipated reductions in leakage associated with these modifications would be approximately 19.0% for the double radial plus axial seals and 31.0% for the double radial plus axial seals.

- The scope of this proposal does not include any damper actuators, controls, instrumentation, ash handling equipment, foundations, access platforming or modifications to the client's existing platform and structures required to accommodate and support the proposed new primary air system.

No appreciable change in performance characteristics is anticipated for future operation of subject units following the proposed modifications. However, due to slightly higher design flue gas temperatures leaving the new tubular primary heater, thermal efficiencies will be slightly lower (less than 0.2% lower) than for the original contract design. Due to reduced secondary air and flue gas flows, future operation of the Ljungstrom air heaters will result in lower air and gas side pressure drops, slightly higher air outlet temperatures, and approximately the same gas outlet temperatures as predicted for the original contract design.

2.3 Separate Steam Coil Heater

A third alternative for creating a separate primary air system was also considered. This option would be similar to the previously mentioned tubular air heater alternative but would employ a steam coil type exchanger for heating the primary air and would not require any flue gas ductwork. Performance, anticipated for future operation with this system, would be characterized by high thermal losses associated with the steam condensate leaving the new heater and, due to reduced secondary air flows, increased flue gas temperatures leaving the existing Ljungstrom heaters.

Due to the anticipated reduction in thermal efficiency of approximately 0.5%, for the additional heat loss in the flue gas, plus approximately 1.0% for the total steam heater condensate loss, this option has not been pursued.

3.0 OPTION B - FLUE GAS AND FLUE GAS PLUS AIR PULVERIZED COAL DRYING AND CONVEYING SYSTEMS

In addition to the segregation of the primary and secondary air systems, ABB-CE Services has also investigated the possibility of utilizing hot combustion flue gases as a potential means of drying and conveying the pulverized coal at this station. The specialized technologies associated with this method of drying and transporting pulverized fuel are available and are currently in use on many low volatile high ash European coal fired installations. However, ABB-CE Services does not consider these technologies to be compatible with the type of fuel or equipment in use at this mill, and for the following reasons, does not consider this method of operation to be suitable for this application.

3.1 Flue Gas Alone as the Drying/Transport Medium for the Pulverized Fuel

To the best of ABB-CE Services knowledge, an inert medium (hot flue gas) has not been tested or used as a method of drying and transporting high volatile North American Bituminous coals with the type of pulverizing and fuel firing equipment in service at this station.

Because of the extremely low O_2 levels present in the pulverized coal/flue gas stream entering the furnace through the burner register coal bucket and because of inadequate mixing anticipated between the fuel and secondary air streams, it is ABB-CE Canada's opinion that this method of operation would be characterized by poor flame stability, poor turndown and high carbon loss from the unit.

Suction type pulverizer, such as those employed at this mill, utilize a counterbalanced style of damper, located on the hot air inlet ducting, as the means of introducing tempering, ambient boiler house air to the system. Assuring a totally inert environment (ie. no tempering air) within this coal pulverizing/transport system would require the installation of dual hot and cool flue gas extraction booster systems to satisfy both the drying and tempering requirements of the mills. Such a system would be both costly and difficult to control.

The use of flue gas in the pulverizer system would act as a form of gas recirculation within the boiler. Higher gas mass flows and velocities associated with this recirculation would result in accelerated ash erosion rates and increased heat transfer to the convective heating surfaces. Additional heat absorbed by these surfaces could result in metal temperatures which exceed the design limitation of the existing materials and could result in reheater and main steam temperature control problems. Therefore, any modification of this nature would require a thorough reassessment of existing boiler surfacing and materials.

3.2 Flue Gas Plus Air as the Drying Transport Medium for the Pulverized Fuel

The blending of relatively small quantities of high temperature (ie. 2000°F) flue gas with ambient boiler house air could satisfy the drying and transport requirements of the existing pulverizers, eliminate the need for a primary air heater and minimize the impact of the recirculated gas on burner stability, turndown, carbon loss, erosion, metal temperatures and steam temperature control. However, the availability of suitable, reliable and cost effective ducting, dampers, blending, extraction/booster and dust collecting equipment, required for such a system, is questionable.

High tempering air flows required with this system would result in reduced secondary air flows, increased Ljungstrom air heater gas outlet temperatures and lower thermal efficiencies, as was the case with the steam air heater alternative described in Option A-3 of this proposal.

Due to the high gas temperatures associated with operation of this type, the potential for overheating of the pulverizer components and fuel piping and the increased potential for mill fires are areas of major concern. Particular attention would be required with such an application, in assessing and implementing the controls and interlocks necessary to assure acceptable mill temperatures under all operating conditions. Further, before condoning any modification of this type, ABB-CE Services would first have to perform a thorough assessment of anticipated performance, materials and heating surface requirements and perform full scale fuel burn tests.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on its evaluation, ABB-CE Services concludes that:

- The separate primary air heating schemes, outlined in Option "A" of this report, represent current proven air heating technologies, employ materials and equipment with proven track records, and afford a cost effective means of satisfying this client's overall objectives, while assuring the future, safe, reliable and efficient performance of these units.

- The various gas and gas plus air pulverized fuel drying/transport systems, described in Option "B" of this proposal, represent technologies which are unproven for applications of this type and which are not compatible with the pulverizing/drying and firing systems presently employed on these units. In addition, such a system could adversely affect present performance and heating surfaces, lead to accelerated erosion rates, and poses serious concerns with respect to the safety, reliability and efficiency of future operation.

Based on the observations cited in this report and the conclusions outlined above, it is ABB-CE Services recommendation that a separate primary air heater system, such as that proposed in Option A 1 or 2 of this report, affords the most effective means of achieving the overall objectives of this project, while assuring the future, safe, reliable, efficient performance of the equipment in question.

ABB
ASEA BROWN BOVERI

January 22, 1991

Fenco Shawinigan Engineering
5657 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

Attention: Mr. John Shanahan

Dear Mr. Shanahan:

Further to my letter of January 16, 1991, the following represents a revised version of my original document, which has been updated to include all outstanding information.

NO_x and SO_2 Emissions

The formation and ultimate emission rates of NO_x and SO_2 compounds from fossil fired furnaces is governed by the complex interactions of numerous physical and chemical variables. These variables include such factors as furnace and fuel/combustion air system geometry, operating practices and fuel chemistry, to name a few. In addition, no direct relationship exists between the ultimate emission rates from a given boiler and fuel nitrogen-sulphur content and firing rates alone.

With due consideration to the above, no predictions of anticipated NO_x and SO_2 emission levels can be made, for this application, based solely on the reductions in coal consumption associated with the proposed combustion of methane gas. However, for comparative purposes, the reduction by weight of total nitrogen and sulphur contained in the fuel fired in each of the three cases operating with MRA, compared to Case No.1 Baseline Performance, is presented in the performance tables presented herein.

Air Preheater Evaluation

In its interim report of December 1990, ABB-CE Services provided an assessment of potential methods of effectively preheating and segregating the primary and secondary air systems on subject units. Subsequent to this report, one of these methods, involving modification of the existing Ljungstrom heaters, was selected by the committee (Nova Scotia Power - minutes of meeting 90/12/18) for further, more detailed evaluation. Based on this new mandate, ABB-CE Services requested selections and performance of Howden Sirocco Canada for modification options to the existing Ljungstrom heater.

ABB Combustion Engineering Services

Combustion Engineering Canada Inc.
501-99 Bank Street
Ottawa, Ontario
K1P 6C5
Telephone (613) 560-4546
Telefax (613) 560-4743
Telex 053-3594 SUPERHEAT

Listed below is a brief summary of ABB-CE's comments regarding the major advantages and disadvantages of each of these options, based on its observations and on Howden Sirocco Canada's feedback.

1) Conversion of both existing Ljungstrom heaters to quadsectors.

Advantage:
- Low secondary to primary air entrainment (approximately 18,000 lb/hr with 24 sector conversion, double seals plus forced air) and no secondary air to gas leakage.

Disadvantages:
- Most costly option.
- Prototype in nature, as this concept has never been used for such an application before.
- High secondary air side pressure drop.
- Actual feasibility has not been finalized and would require further evaluation by Howden.
- Air inlet and outlet ducting arrangement would be complicated and costly.
- Relatively high total air to gas leakage.

2) Conversion of one existing Ljungstrom heater to trisector duty and upgrading the seals on the remaining, existing Ljungstrom.

Advantages:
- Simplified primary air ducting arrangement.
- Low secondary to primary air entrainement (approximately 10,000 lb/hr, with 24 sector conversion, double seals plus forced air).
- Proven design.
- Relatively low total air to gas leakage rates.
- The modifications to the Ljungstrom heaters would be slightly less costly than for either of the other two options. However, the increased scope of primary and secondary air ducting required with this option would tend to offset these savings.

Disadvantages:
- Operation and control of the combustion air systems would be difficult with this option.
- High primary air side pressure drop.
- High secondary air to gas entrainment/leakage (approximately 15,000 lb/hr total, with forced air on both heaters).
- Actual feasibility requires further evaluation by Howden Sirocco Canada.

3) Conversion of both existing Ljungstrom heaters to trisector duty.

Advantages:
- Proven design.
- Less costly than quadsector option.
- Reasonable secondary air to gas leakage and secondary air to primary air entrainment rates (approximately 3,000 lb/hr and 17,000 lb/hr respectively with 24 sector conversion, double seals plus forced air).
- Balanced, workable primary and secondary air ducting arrangement.
- Reasonable air and gas side pressure drops.
- Relatively low total air to gas leakage rate

Disadvantages:
- As is the case with all three options outlined herein, the ultimate feasibility of this option would require further evaluation by Howden Sirocco Canada.

Based on this evaluation, the conversion of both existing Ljungstroms to trisectors with 24 sectors, double seals plus forced air was selected as the most appropriate option for this application and is the basis for the following Case No. 2, 3 and 4 boiler performance assessments.

Performance Assessment

Predicted performance data, for each of the cases listed below, is based on a single boiler operating at 100% of original contract design M.C.R. (ie, 1,080,000 lb/hr main steam and 958,000 lb/hr reheat steam flows) and the following coal analysis.

Component	% Wt
Carbon (C)	65.90
Hydrogen (H)	4.30
Nitrogen (N)	1.30
Oxygen (O)	5.50
Sulphur (S)	3.00
Moisture	9.00
Ash	11.00
HHV (Btu/lb)	11,695

1) Baseline performance for operation with coal as the only fuel.

Total Coal Consumption	58.526 tonnes/hr
- F.D. Fan power requirement per fan (approximately)	390 KW
- I.D. Fan power requirement per fan (approximately)	750 KW

2) Performance based on the total available MRA, of 380 m³/sec at 60°F and 0.66% methane by volume, being equally distributed to the secondary air systems of all four units.

Total Coal Consumption	55.757 tonnes/hr	
- Total methane consumed in furnace	0.625 m³/sec	
- Methane contained in primary air to mills	0.009 m³/sec	
- Methane concentration in primary air to mills	0.04% by volume	
- Methane lost to flue gas	0.002 m³/sec	
- F.D. Fan power requirement per fan (approximately)	340 KW	saving = 50kW
- P.A. Fan power requirement per fan (approximately)	150 KW	extra = 150 -
- I.D. Fan power requirement per fan (approximately)	750 KW	saving = 0
- Reduction in nitrogen and sulphur, contained in the fuel fired, compared to baseline performance	4.73% by weight	

3) Performance based on MRA, at 60°F and 0.71% methane by volume, constituting 100% of the secondary air supply to the unit.

Total Coal Consumption	54.688 tonnes/hr	
- Total methane consumed in furnace	0.863 m³/sec	
- Methane contained in primary air to mills	0.013 m³/sec	
- Methane concentration in primary air to mills	0.06% by volume	
- Methane lost in flue gas	0.002 m³/sec	
- F.D. Fan power requirement per fan (approximately)	340 KW	as for (2)
- P.A. Fan power requirement per fan (approximately)	150 KW	
- I.D. Fan power requirement per fan (approximately)	750 KW	
- Reduction in nitrogen and sulphur, contained in the fuel fired, compared to baseline performance	6.56% by weight	

4) Performance based on MRA, at 60°F and 0.86% methane by volume, constituting 100% of the secondary air supply to the unit.

Total Coal Consumption	53.839 tonnes/hr	
- Total methane consumed in furnace	1.046 m³/sec	
- Methane contained in primary air to mills	0.015 m³/sec	
- Methane concentration in primary air to mills	0.07% by volume	
- Methane lost in flue gas	0.003 m³/sec	
- F.D. Fan power requirement per fan (approximately)	340 KW	as for (2)
- P.A. Fan power requirement per fan (approximately)	150 KW	
- I.D. Fan power requirement per fan (approximately)	750 KW	
- reduction in nitrogen and sulphur, contained in the fuel fired, compared to baseline performance	8.01% by weight	

5) Performance based on MRA, at 60°F and 1.3% methane by volume, constituting 100% of the secondary air supply to the unit.

Total Coal Consumption	51.305 tonnes/hr
- Total methane consumed in furnace	1.593 m^3/sec
- Methane contained in primary air to mills	0.023 m^3/sec
- Methane concentration in primary air to mills	0.11% by volume
- Methane lost in flue gas	0.004 m^3/sec
- F.D. Fan power requirement per fan (approximately)	340 KW
- P.A. Fan power requirement per fan (approximately)	150 KW
- I.D. Fan power requirement per fan (approximately)	750 KW
- Reduction in nitrogen and sulphur, contained in the fuel fired, compared to baseline performance (Case 1)	12.34% by weight

as 1a (2)

Regards,

W.L. Routly
ABB Combustion Engineering Services Division
Services Engineering

WLR/jn

58613-03

ABB
ASEA BROWN BOVERI

February 1, 1991

Fenco Shawinigan Engineering Ltd.
Suite 200, Park Lane Terraces
5657 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

[illegible]

Attention: **Mr. John Shanahan - Project Manager**

Subject: **Lingan-Phalen Mine Methane Study**

Dear Sir:

In response to your most recent requests, please find enclosed ten (10) copies of our revised drawings as well as pricing information as follows:

1. The most practical option (A.) was previously estimated to cover the supply and erection of Ljungstrom airheater modifications along with separation of the primary and secondary air streams. This price was offered as:

.........2.8 Million Dollars.........

2. We have further developed this estimate to include scope items not typically carried by ABB C-E which or were not well defined at the study stage and required making some gross assumptions. Also we had not received a well defined price from Howden for airheater modification. The items which were added include:

I. Instrumentation and Controls Upgrades*

A. FSSS Alterations

- New Cabinet with Card Rack, Power Supplies, Terminals, Simulator Section, Prewired and Factory Tested
- FSSS Panel Insert
- Preconnectorised Cables (30m)

B. Boiler Control Items

- New Primary Air System Damper Drives	8
- New Pressure Transmitters	6
- New Temperature Transmitters	6

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C. Analog Control Logic Modifications

- Foxboro Analog Control System Alterations
  via spec. 200 hardware

* These estimates were prepared as "order of magnitude" prices which are considered accurate within plus/minus 35%. We have included no price for electric motor control centers or wiring Engineering and supply.

II. Miscellaneous Construction Scope**

- Platform Changes
- Interference Resolution
- Minor Structural Changes
- Fan/Motor Footing
- Installation of Dampers/Drives

III. Additional Air Heater changes requested by customer

3. The new price covering the original quote of $2,800,000.00 plus the items quoted in this letter will be:

..........3.7 Million Dollars..........

** These additions were roughly prepared under the situation where drawings of the structural steel and platforms were not available. Therefore an accurate assessment of changes to the existing structure and new supports was not possible. Existing space availability required to accommodate, maintain and support the proposed new Primary Air Fans, drives, ducting and steam airheaters were visually surveyed.

The situation for each unit is different, there could be some location problems on Primary Air installations for Units 2, 3, and 4. Therefore this would require further customer/ABB consultation on impact of Engineering and Construction hours for the final proposal.

Yours truly,

Larry Tyer
For

W. Ross MacDonald
Supervisor - Engineering Services

VIA TELECOPIER

February 5, 1991

ABB Combustion Engineering - Fossil Services Canada
Technical Services Department
Suite 501, 99 Bank Street
Ottawa, Ontario
K1P-6C5

Attention: Mr. W. Ross MacDonald

Dear Sir:

RE: Lingan/Phalen Mine Methane Study - Capital Cost Estimates

Thank you for your letter of February 1st in which revised cost estimates, including for I&C items and boiler specific construction issues were presented.

We have a number of questions in regard to these cost estimates which require a written ABB-CE response before February 8th:

1 The RFP (section 4.11) specifically requests costs to be presented in sufficient detail so as to permit "critical review". We would like a breakdown of the cost estimates into the following areas:

    1.1 Ljungstrom air heater modifications (This should be backed up by Howden correspondence as it is implied that you have received this)

    1.2 PA and FD ductwork modifications, incl struct. steel

    1.3 PA fans, including pedestals/ footings

    1.4 Instrumentation & Controls including dampers and actuators

    I&C costs (item 1.4) are presumed to be accurate to +/- 35%. What is the level of estimating accuracy for the costs you have lumped into section II? We have assumed that the original quote of $ 2.8 million is accurate to +/- 15%. If this is not the case, please confirm the estimating accuracy.

2 Is any contingency allowance included in your estimates?

3 Do these estimates include for any EPCM (Engineering, Procurement and Construction Management) costs? If so, please indicate these costs separately.

4 Please confirm that all costs are in December 1990 dollars.

5 What are the "additional air heater changes" requested by the customer in your section III)?

6 Under I&C item B, please confirm quantities of Transmitter devices.

7 Please clarify if the total costs for the entire plant are four times the unit price as quoted. It would seem that some cost reduction should apply on account of common costs.

Yours truly,

FENCO SHAWINIGAN (1985) ENGINEERING LIMITED

John N. Shanahan
Project Manager

JNS/jh
58613N75.L

cc: D. Granatstein

ABB
ASEA BROWN BOVERI

February 7, 1991

Fenco Shawinigan Engineering Ltd.
5657 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

Attention: **Mr. John N. Shanahan - Project Manager**

Subject: **Lingan/Phalen Mine Methane Study - Capital cost Estimates**

Dear Sir:

In response to your letter of February 5th, we are pleased to provide the following information regarding our previous estimates submitted to you on February 1st.

1.1 Ljungstrom Airheater Modifications

Please note that the estimate submitted contains a figure for airheater changes (Material, Engineering and Drafting) which is based upon a verbal commitment only from Howden. Due to the complexity of the changes, the relative lack of experience with this type of retrofit, and the concern for internal clearances, we were not able to obtain an estimate with a higher level of confidence at this time. We would be pleased to update this price when Howdens has responded to our requests. No field construction price has been included.

..........$1,000,000.00 per unit* (2 airheaters)..........

1.2 Primary Air and Forced Draft Ductwork Modifications

..........$1,850,000.00 (per unit)..........

1.3 Primary Air Fans

..........$225,000.00 (per unit)..........

../2

ABB Combustion Engineering Services

Combustion Engineering Canada Inc.
801-99 Bank Street
Ottawa, Ontario
K1P 6C5
Telephone (613) 560-4546
Telefax (613) 560-4743
Telex 053-3394 SUPERHEAT

1.4 Instrumentation and Controls

..........$645,000.00 (per unit)..........

2. Yes. 25%

3. Yes. 20%

4. Costs are in December 1990 Dollars.

5. Please disregard this as it referenced scope requested by Brian King (inlet ducts to PA fans).

6. Six transmitters each for pressure and temperature were included.

7. Savings on Engineering, Drafting etc. should reduce the total plant price as follows.

1st Unit	$3.7 Million
2nd, 3rd, 4th Units	$9.9 Million (based upon 1.2 Million Savings) 13.6

Please note that the original estimate of $2.8 million dollars was offered based upon very limited information and considered to be a "wise" guess with accuracy not even determinable. Since the options have been narrowed down we have refined our numbers and added scope in accordance with your requests. Although the material estimates provided are quite accurate for the sizes of ducts shown on our drawings and assume no layout or space problems, should any increases in duct runs or sizes occur it would have a significant impact upon the prices. We feel confident the pricing information at this point is probably accurate within plus/minus 25% assuming there are no major changes or space limitations.

The final note of importance is that we are presently carrying estimates for major vendor vendor equipment supplied to us (fans, airheater etc) at cost plus 15% handling fee.

I trust this will satisfy your requirements as transmitted on February 5, 1991 and look forward to further cooperation on the project.

Sincerely yours,

W Ross MacDonald

W. Ross MacDonald
Supervisor - Engineering Services

Lavalin

IGN BRIEF PAGE 1 of 2

PROJECT 58613 - LINGAN METHANE

Department Project No 58613 Act A1 Sub 1 01 Sub 2 10 Sub 3 00

ETAILS CAP. COST EST. (ABB-CE) REF. ABB-CE LETTER 91/02/07

REPARED BY (rint) SNS. (initials) DIVISION DATE Y 91 M 02 D 08

VERIFIED BY (rint) (initials) DIVISION DATE Y M D

Air heaters	1,000,000	27%
PA/FD ducting	1,850,000	50%
PA Fans	225,000	6%
I & C	645,000	17%
	3,720,000	100%

all estimates include 25% contingency.

all estimates include 20% EPCM.

thus, base direct cost (no ctgy. & EPCM) must be calculated. (call this "x")

total plant (4 boilers) cost = 13.6 million

$$13.6 = [x + (x \times 0.25) + (x \times 0.2)]$$

$$= [x + .45x]$$

$$\& \quad x = 9.38$$ million

ESIGN BRIEF

PAGE 2 of 2

PROJECT LINGAN METHANE

Department E Project No 52613 Act A1 Sub 1 01 Sub 2 1 Sub 3 000

ETAILS CAP. COST EST. (ABB-CE) REF. ABB-CE LETTER 91/02/07

PREPARED BY (print) (initials) DIVISION DATE Y M D

ERIFIED BY (print) (initials) DIVISION DATE Y M D

base direct cost is 9.38 million

⇒ Air heater mods = 9.38 × 0.27 = 2.532 million

PA/FD ducting = 4.69 "

PA fans = $ 562,000

I & C = 1.595 "

(for four boilers)

ABB
ASEA BROWN BOVERI

March 13, 1991

RECEIVED
MAR 18 1991

Fenco Shawinigan Engineering Ltd.
5657 Spring Garden Road, Suite 200
Halifax, Nova Scotia
B3J 3R4

Attention: **Mr. John N. Shanahan - Project Manager**

Reference: **Lingan/Phalen Mine Methane Study - Corrections to Final Report**

Dear Sir:

In response to your letter of February 26, 1991 we are pleased to provide input to the final report corrections as follows:

1. We confirm that our letter of 90/12/12 has been completely superseded by our letters of 91/02/01 and this letter. You may delete the 90/12/12 letter from the final report.

2. I believe the latest revised airheater air/gas flows and leakage rates have been revised to your satisfaction. We will consider our obligations fulfilled with respect to this matter.

3. Can you please advise what exact format will be required for the ABB Combustion Services drawings.

4. Cost and schedule estimates have been revised and updated as per your requirements as follows:

    a. Outage Requirements - at this point we are confident that either the tubular air heater installation or Ljungstrom modifications option can be completed according to one of two possibilities. In either case we believe a three week period would be required, at eight regular hours per day, to complete all possible work with the boilers on line (per unit). If the outage work was completed on an eight hour regular (Mon. - Fri.) shift per day we would need five weeks duration.

If the outage work was carried out with two ten hour shifts per day (Mon. - Fri.) we could reduce the duration to three weeks (fifteen days, Mon. - Fri.) per boiler outage.

Option 1 (1-8 hr. shift per day)	Option 2 (2-10 hr. shifts per day)
1. On line Work - 15 days (8hrs/day, Mon-Fri)	15 days (8hrs/day, Mon-Fri)
2. Outage Work - 25 days (8hrs/day, Mon-Fri)	15 days (2x10 hrs/day, Mon-Fri)
TOTAL 40 Days	30 Days

b. Tubular Airheater Pricing

Total price including I&C upgrades and miscellaneous construction scope included in our previous letters:

..........**4.1 Million Dollars per unit (Dec. 1990 Dollars)**..........

All previously quoted conditions apply to this price in terms of accuracy, contingency and scope.

c. Price Variance with Shift Options (Dec. 1990 Dollars)

	Ljungstrom Mods (Millions)	Tubular Inst. (Millions)
Option 1	3.7	4.1
Option 2	3.8	4.2

Again we feel these prices reflect the worst case scenario and would welcome the opportunity to revisit our estimates during a phase where some of the unknowns can be eliminated.

In closing, we trust these few lines will meet your requirements in submitting the final report, and encourage further cooperation in bringing this important project to fruition.

Sincerely yours,

W. Ross MacDonald, P.Eng.
Supervisor - Engineering Services
ABB Combustion Services Division

CAPE BRETON
DEVELOPMENT
CORPORATION

SOCIÉTÉ DE
DÉVELOPPEMENT
DU CAP-BRETON

FAX MESSAGE

1991-02-20

Dr. David Granatstein, P.Eng.
Chairman
Technical Steering Committee
Mine Methane Utilization Project
Nova Scotia Power Corporation
P. O. Box 910
Halifax, N.S.
B3J 2W5

Dear Dr. Granatstein:

Re: Methane Release in Coal Mills

In response to the request at our meeting of 1990-02-19.

Measurements we have made of the methane content of our coal at various stages indicate that the greatest likely content for fresh mined coal delivered to the mills at Lingan Generating Station would be about 150 standard cubic feet per ton. This for Run of Mine coal delivered directly from Lingan or Phalen to Lingan Generating Station without washing and fed directly to the boilers without stockpiling.

Based on a fuel flow of 125,500 lbs./hr. (page 3-6) and Primary air flow of 17,124,000 cu. ft./hr. x 0.18 = 3,080,000 cfh (page 3-8).

This indicates a maximum methane content of 0.3% for the primary air. [(125,000/2000)*150]/3,080,000.

The above is based on the following assumptions:

1) That methane completely desorbs from the coal in the mills.

2) That methane available to be desorbed does not increase with temperature. We have evidence that increasing temperature increases both the rate of desorption and the total desorbed (it follows an exponential decay curve). However, we do not have data that can be extrapolated to the mill temperatures which I suspect are greater than 100°C.

Canadä

For the coal which is normally delivered to Lingan, mostly Run of Mine Prince which has a very low methane content, mixed with washed Phalen and Lingan thermal coal in a large stockpile methane content should be an order of magnitude less than calculated above for fresh coal. This would result in methane content in the primary air of 0.03%. This is the range I would expect it to be in under normal operating conditions unless heating greatly increases the methane available to be desorbed.

If you would indicate the discharge temperaure of the mills we will try to adapt our measuring methods to measure total desorption at that temperature.

Yours truly,

CAPE BRETON DEVELOPMENT CORPORATION

JC Campbell

John C. Campbell, P.Eng.
Sr. Research Engineer

JCC:mlm

APPENDIX 3

DETAILED COST ESTIMATES

The following Code of Accounts was agreed with NSPC for breaking down the capital cost estimates. Some changes have been incorporated to reflect all of the cost components of various options. Where possible, costs have been presented at the 3 digit level within the WBS.

WBS AREA	DESCRIPTION
1	**Site**
11	Land & land rights - general site
112	Surveys
113	Investigations
116	Site preparation
13	Site Access
131	Access roads
15	Site Services & Improvements
158	Lighting in site area (if applicable)
2	**Structures**
21	Powerhouse and Auxiliary Structures
211	Boilerhouse structural steel modifications for MRA ducting, including duct material on boilerhouse, roofing, flashing, etc.
214	Delivery Duct from duct fan to boilerhouse, including breeching from duct fan, duct fan foundations, delivery duct foundations and struct. steel supports.
28	Transmission Duct
281	Duct materials
282	Duct foundations
283	Structural supports
284	Insulation

		285	Liner
		286	Connections to mine fans (breeching)
		287	MDM injection/ mixing
3			**Boilers and Auxiliaries**
	31		Duct Fan, including motor, foundations, etc.
	33		Boiler
		331	Boiler Air Heater modifications (ABB-CE)
		332	PA & FD fan ductwork modifications (ABB-CE)
		333	PA Fans (incl. pedestals & footings) (ABB-CE)
		334	Boiler I & C modifications (ABB-CE)
	34		
		340	Instruments & controls, MRA system
	56		Electrical
		560	all 600/480 volt systems incl. lighting & grounding
		561	4160 volt systems
7			**Common Services**
	73		Building Ventilation & Heating
		731	Plant Ventilation, incl. fans, motors, misc. struct. steel)
8			**Owners Costs**
		825	Construction Costs of temporary services
		828	Commissioning Costs
		851	Consultants Costs

DETAILED COST ESTIMATES

*

WBS AREA	DESCRIPTION	SUPPLY	INSTALL	TOTALS		COMMENTS
1	SITE					
11	Land & land rights - general site					
112	Surveys			0		
113	Investigations			0		
116	Site preparation (incl. mobilization)	100,000	400,000	500,000		
	sub-total area 11:	100,000	400,000	500,000		
13	Site Access					
131	Access roads			0		
	sub-total area 13:	0	0	0		
15	Site Services & Improvements					
158	Lighting in site area (if applicable)			0		
	sub-total area 15:	0	0	0		
	TOTAL, AREA 1:	100,000	400,000		500,000	
2	STRUCTURES					
21	Powerhouse and Auxiliary Structures					
211	Boilerhouse Modifications	incl.	350,000	350,000		
214	Delivery Duct	1,907,000	1,557,000	3,464,000		
	sub-total area 21:	1,907,000	1,907,000	3,814,000		
28	Transmission Duct					
281	Duct materials	4,183,650	548,250	4,731,900		
282	Duct foundations	2,857,000	190,000	3,047,000		
283	Structural supports	2,322,440	230,000	2,552,440		
284	Insulation	667,000	323,000	990,000		
285	Liner			0		incl. in 281
286	Connections to mine fans (breeching)	494,000	178,000	672,000		
287	MDM injection/ mixing	38,000	26,000	64,000		
	sub-total area 28:	10,562,090	1,495,250	12,057,340		
	TOTAL, AREA 2:	12,469,090	3,402,250		15,871,340	

3	BOILERS AND AUXILIARIES				
31	Duct Fan, including motor	761,000	90,000	851,000	
	sub-total area 31:	761,000	90,000	851,000	
32	Delivery Duct - mech. systems	645,000	298,000	943,000	
	sub-total area 32:	645,000	298,000	943,000	
33	Boiler				
331	Boiler Air Heater modifications	incl.	2,532,000	2,532,000	
332	PA & FD fan ductwork modifications	incl.	4,690,000	4,690,000	
333	PA fans (incl. pedestals & footings)	incl.	563,000	563,000	
334	Boiler I&C modifications	incl.	1,595,000	1,595,000	
	sub-total area 33:	0	9,380,000	9,380,000	
340	Instruments & controls (MRA system)	221,775	23,040	244,815	
	sub-total area 34:	221,775	23,040	244,815	
	TOTAL, AREA 3:	1,627,775	9,791,040		11,418,815
56	Electrical				
560	600/480 volt systems	128,775	48,960	177,735	
561	4160 volt systems	98,900	35,550	134,450	
	sub-total area 56:	227,675	84,510	312,185	
	TOTAL, AREA 5:	227,675	84,510		312,185
7	COMMON SERVICES				
73	Building Ventilation & Heating				
731	Plant Ventilation	121,000	96,000	217,000	
	sub-total area 73:	121,000	96,000	217,000	
	TOTAL, AREA 7:	121,000	96,000		217,000
	TOTAL DIRECT COSTS: (excluding contingency)	14,545,540	13,773,800		28,319,340

**FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED**

ESTIMATE WORKSHEET

PROJECT: 58613 - LINGAN
PHALEN MINE METHANE

T.O. BY: D LEGER **PRICED BY:** D LEGER **DATE:** NOV 27, 1990 **SHEET** 1 **OF** 2

JOB NO. 58613 **CLIENT** **TYPE OF ESTIMATE** BUDGET **CKD. BY:**

DESCRIPTION INSTRUMENTATION COST ESTIMATE

ACCT.		QUANTITY	UNIT	COST OR M/HRS PER UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
				MAT.	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
340	CONTROL PANEL	1	EA	2800	100	45	2800	–	–	100	4500	7300
	ANNUNCIATOR - MAIN PANEL	1	EA	2500	11	45	2500	–	–	11	495	2995
	PRESSURE SWITCH	2	EA	240	4.5	45	480	–	–	9.0	405	885
	PRESSURE TRANSMITTER	2	EA	1500	4	45	3000	–	–	8	360	3360
	FLOW COMPUTER	1	EA	2800	3	45	2800	–	–	3	135	2935
	PRESSURE CONTROLLER	2	EA	2400	3	45	4800			6	270	5070
	FLOW TRANSMITTER	1	EA	1500	4	45	1500	–		4	180	1680
	FLOW ELEMENT	1"	EA	58000	30		58000		2250	30	1350	61600
	FLOW COMPUTER	1	EA	2800	3		2800	–	–	3	135	2935
	METHANE COMPUTER & TOTALIZER	1	EA	2800	3		2800	–		3	135	2935
	METHANE DETECTOR	9	EA	2000	3		18000	–	–	27	1215	19215
	CONTROLLER (LOCAL)	1	EA	2000	5		2000	–	–	5	225	2225
	DAMPER OPERATOR (ELEC - PHALEN CV) (MODULATING)	1	EA	(M)	3	45	–	–	–	3	135	135
	SUB TOTAL						101480		2250	212	9540	113270

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT: 58613 - LINGAN
PHALEN MINE METHANE

T.O.BY: D LEGER **PRICED BY:** **DATE:** NOV 27 1990 **SHEET** 2 **OF** 2

JOB NO. 58613 **CLIENT** **TYPE OF ESTIMATE** CL. III **CKD. BY:**

DESCRIPTION INSTRUMENTATION COST ESTIMATE

ACCT.		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
				MAT'L	M/H	LAB$		M/HRS	DOLLARS	M/HRS	DOLLARS	
340	RADIO FREQUENCY LINK - MINE → P.STN.	3	PCS	10000	11	45	10000	–	–	11	495	10495
	VIBRATION MONITOR	1	EA	6690	5	"	6690	–	–	5	225	6915
	WIRING - OUTSIDE 200m RUNLENGTH	LOT	FT				3500	–	–	200	9000	12500
	INSIDE											
	DAMPER ACTUATOR - VARIABLE INLET VANES	1	EA	4000	13	45	4000	–	–	13	585	4585
	EXISTING BOILER INTERFACE - ELEC CARDS	4	LOT	15,000	–		60.000				–	60,000
	JUNCTION BOX - FAN AREA	1	EA	700	5	45	700	–	–	5	225	925
	DAMPER (S/D @ BOILER MRA)	4	EA	–	9	45	405	–	–	36	1620	2025
	MDM SAFETY SHUTDOWN VALVE (FM & UL)	1	EA	10,000	6	45	10000			6	270	10270
	SIZE 8 INCH?											
	MDM BACK PRESSURE VALVE	1	EA	16,000	2	45	16000	–	–	2	90	16090
	ANNUNCIATOR AT EACH MINE CONTROL ROOM	2	EA	2000	11	45	4000	–	–	22	990	4990
	MISC. FITTINGS, MATERIAL	LOT	–	–	–	–	5.000	–	–	–	–	5000
	SUBTOTAL						120 295	–	–	300	13500	133,795
	P1 + P2 TOTAL						221,775		2250	512	23040	247,065
✓												

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT: X

REV 3 JAN 24, 199
REV 2 JAN 3, 199
REV 1, DEC 12, 199C

T.O.BY:
PRC'D BY: M. MACDONALD
JOB NO. 58613
CLIENT
DATE: 90-12-11
SHEET 1 OF 2
DESCRIPTION
TYPE OF ESTIMATE
CKD. BY:

ACCT.		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
				MAT'L	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
561	CABLE TRAY - ALUMINUM - 450mm LADDER TYPE	300	m	60	1	45	18000			300	13500	31500
	BARRIERS	600	m	4	.2	45	4200			120	5400	9600
561	5KV 3 CONDUCTOR, UNSHIELDED TECK CABLE.	300	m	150	.5	45	45000			150	6750	51750
561	PROTECTION TO BE ADDED TO SPARE BREAKER CELL.						15000			40	1800	16800
561.	CONTROL CABLES 2X 10C 600V CONTROL CABLE.	600	m	15	.20	45	9000			120	5400	14400
561.	MISC. HARDWARE - STRESS CONES, CONNECTORS, ETC.						5000					5000
561.	RTD CABLE (5 TRIAD'S) 600V (BEARINGS & STATOR TEMPS)	300	m	9	.2	45	2700			60	2700	5400
	TOTAL WBS # 561						98,900				35,550	134450
560	GROUNDING & LIGHTING						10000			150	6750	16750
560	1000 V POWER CABLE (3 COND) #8 AWG (DAMPER CONTROL	300	m	11	.2	45	3300			60	2700	6000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT:

REV 3 JAN 24, 1991
REV 2 JAN 3, 1991

T.O.BY:
PRICED BY: H MACDONALD
DATE: 91-01-03.
SHEET 2 OF 2
JOB NO. 58613
CLIENT
TYPE OF ESTIMATE
CKD. BY:
DESCRIPTION

ACCT.		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
				MAT'L	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
560	CABLE TRAY - ALUMINUM 300 mm											
	LADDER TYPE.											
	100 METRES PER UNIT	400	m.	.50	1	45	20000			400	18000	38 00
560	CABLE BASED ON 200HP P.A MOTORS.											
	250 MCM TECK (POWER) 1000V											
	100 m X 8 MOTORS	800	m	.55	.15	45	44000			120	5400	49 40
	($55000 /km)											
	#12 AWG. TECK (CONTROL) 600V											
	100 m X 8 MOTORS	800	m.	4.34	.10	45	3475			80	3600	7075
	($4344 /km).											
560	MISC. CONTROL START/STOP, ETC.	8		1000		45	8000			150	6750	14750
560	ONE MCC SECTION PER UNIT	4.		10000	32	45	40000			128	5760	45 76
	(TWO SIZE 5 STARTERS PER MCC											
	SECTION											
	TOTAL WBS # 560						128,775				48,960	177,735

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET PROJECT:

T.O.BY: PJ Mahon
PRICED BY: PJ Mahon
DATE: Dec 19, 1990
SHEET 1 OF 8
JOB NO. PJ 58613
CLIENT Com. on Alt. Coal
TYPE OF ESTIMATE Study
CKD. BY:
DECRIPTION Summary of Estimate

ACCT.		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
				MATL	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
286	Pace1 (Phalen)						255,000				105,000	
286	Pace2 (Lingan)						239,000				73,000	
287							38,000				26,000	
31							761,000				90,000	
32							645,000				298,000	
214							1,907,000				1,557,000	
211							Incl.				350,000	(Mat'l & Labour)
731							121,000				96,000	
	Subtotal						3,966,000				2,595,000	6,561,000

APPENDIX 4

LIST OF DRAWINGS

The following drawings have been produced as part of the study:

A4.1 F.S.E.L. DRAWINGS:

A4.1.1 Civil Drawings

58613 - C - 01/A	Key Plan
58613 - C - 02/A	Existing Conditions
58613 - C - 03/A	Alternate Routes - Plans
58613 - C - 04/A	General Arrangement
58613 - C - 05/A	Section, Elevation & Details

A4.1.2 Instrumentation Drawings

58613 - J - 01/A	P & I D

A4.1.3 Mechanical Drawings

58613 - M - 01/A	Lingan Fan Connection & MRA / MDM Blending
58613 - M - 02/A	Phalen Fan connection, Layout
58613 - M - 03/A	Duct Fan & Generating Station Interface

A4.2 ABB-CE DRAWINGS

G - MMS - 587 - 01/1	Proposed Trisector Primary Air Arrangement, Option "A", Alternative #1
G - MMS - 587 - 02/0	Proposed Tubular Air Heater Arrangement, Option "A', Alternative #2
Sketch #1	Schematic Gas and Air Flow Diagram

90.08.08

Nova Scotia Power Corporation
P.O. Box 910,
Halifax, Nova Scotia
B3J-2W5

Attention: Dr. D. Granatstein, P. Eng.,
Chairman, Technical Steering Committee

Dear Sir:

RE: Lingan / Phalen Mine Methane Utilization Study

Fenco Shawinigan Engineering (1985) Limited (FSEL) is pleased to submit herewith, ten (10) copies of the Interim Report for the above project.

The Interim Report details the work performed to date on his project, the preliminary conclusions drawn by the Study Team and makes specific recommendations for focussing the study for the remainder of the project.

Should you require further information or discussions regarding any aspect of this Interim Report, please feel free to contact the undersigned.

We look forward to the August 16th meeting with the Committee on Atlantic Coal and other invited personnel in order to present the report and discuss the implications contained therein.

Yours truly,

FENCO SHAWINIGAN ENGINEERING (1985) LIMITED

John N. Shanahan
Project Manager

JNS/dc

cc A. Crandlemire, NSDME

APPENDIX 5

INTERIM REPORT

TECHNICAL REPORT
TECHNICAL/ECONOMIC OF THE FEASIBILITY OF SUPPLYING AND UTILIZING LINGAN/PHALEN MINE METHANE AT LINGAN GENERATING STATION

Interim Report

August 8, 1990

EXECUTIVE SUMMARY

1.0 INTRODUCTION

The Committee on Atlantic Coal (CAC) commissioned Fenco Shawinigan Engineering Limited (FSEL) to undertake a study to determine the most attractive way of utilizing two sources of methane which emanate from Cape Breton Development Corporation (CBDC) coal mining operations at Lingan and Phalen Mines. This study is a follow-on from previous work carried out by FSEL [Ref. 1 & 2]. This report reflects the interim findings of the Study Team.

The first source of methane is in the ventilation air which is used primarily to purge the mine workings of methane which escapes from the coal as it is being mined. At the discharge point to atmosphere, this Mine Return Air (MRA) contains 0.4 - 0.6% methane. The second source of methane comes from a system of suction pipework driven into the rock strata forming the roof above the coal seam. As the coal is removed and the roof collapses, Mine Drainage Methane (MDM) collects in the strata and is then extracted, at concentrations of about 50% methane and 50% air, to atmosphere.

This study scope looks at methods of utilizing MRA and MDM both separately and in combination:

- MRA alone used as combustion air
- MDM alone used as a "reburn" fuel
    - with simple compression
    - with gas beneficiation
- MRA blended with MDM, used as combustion air

2.0 PRELIMINARY CONCLUSIONS

2.1 Use of MRA as Combustion Air

The study shows that the findings of the 1983 FSEL study on this option [ref 1] are still valid. Ducts of about 3.4 m diameter would feed from Lingan mine and Phalen mine ventilation fans, to a common 4.8 m diameter duct. This large duct would follow a route yet to be defined in Phase II of this study. There are at least three plausible routes which are currently (July 1990) being explored. The interface with the Lingan Generating Station is seen as comprising a suction fan adjacent to the main boiler house building feeding to a duct high on the building with delivery spouts to each of the four boiler forced draft fan intakes.

2.2 Use of MDM

A series of combustion tests were conducted at CANMET Laboratories June/July 1990 which showed that by using MDM (50% methane), in a single boiler, NO_x emissions from that boiler could be reduced by about 15%. The MDM would actually displace about 8% of the coal fuel. Reduction of NOx equates to about 210 tonnes/ year with a 20 year life-cycle cost of $1,801 per tonne. Methane can also be concentrated from 50% to 90% by a Pressure Swing Adsorption process (PSA). With this concentrated methane, NO_x could be reduced by about 20%. Under this scenario, reduction of NOx equates to about 340 tonnes/ year with a 20 year life-cycle cost of $1,756 per tonne. Note that for both the MDM (50% methane) and concentrated MDM (90% methane) scenarios, the life-cycle costs and benefits were assumed to be incremental over the base case of using MRA alone, as this base project was found to be viable on it's own merits.

The only incremental benefit which would be realized by MDM combustion over and above those acheivable by blending MDM with MRA are the incremental NO_x reductions. Out of interest, the cost/benefit analysis of using MDM as a fuel proved to be attractive. However, almost all of the benefits can be achieved at a fraction of the costs by blending MDM with MRA at the mine.

NSPC indicated at a progress meeting July 1990, that the incremental costs of reducing NO_x using MDM are not encouraging as other technologies could achieve a reduction in NO_x at less cost/tonne. Based on this, a decision was made that the balance of this study would focus on blending MDM with MRA and conveying the blend from both Lingan and Phalen mines for use as combustion air at Lingan Generating Station.

2.3 Use of MRA and MDM blended as Combustion Air

At Lingan Mine, the MRA fan and the MDM extraction system are separated by less than 100 hundred metres. It is envisaged that a pipe will be run from the MDM to the MRA system where the MDM will be blended with the MRA. The methane concentration of the combined MRA and MDM streams will be approximately 0.8%. The incremental cost over the simple MRA project is less than $ 0.5 million, yet the benefits are nearly doubled. This is therefore the project recommended for Phase II.

3.0 LAND USE AND ENVIRONMENTAL CONTEXT

No significant regulatory impediments to the proposed project have been identified. There are legislative requirements for review of the project which should lead to the granting of the required permits. Although no regulations specifically focus on the aesthetic or visual impact of the project, this issue may be raised. To the extent possible, the routing should be kept at some distance from the public highway. Alternatively the duct should be buried or partially buried. The increased cost of full burial of the duct is likely to be several million dollars. Thus it should only be considered after a detailed assessment of the project viability. This assessment may include the notional monetary value for reducing SO_2 emissions.

TABLE E-1

COMPARATIVE COSTS, BENEFITS AND EMISSION REDUCTIONS

		MRA alone	MDM compression alone	MDM beneficiation alone	MRA/MDM blend	MDM compression (increm. over blend)	MDM beneficiation (increm. over blend)
Present Value of Costs	Direct ($m)	13.6	2.6	3.6	14.1	2.6	3.6
	Indirect ($m)	7.1	1.43	2.0	7.3	1.43	2.0
	O&M ($m)	8.1	5.48	9.6	7.8	3.54	5.8
	Total Costs	28.80	9.51	15.20	29.20	7.57	11.40
Benefits	Coal saved ($m)	35.6	29.51	29.51	65.1	0.00	0.00
	net SOX reduced (t/yr)	1,546	1,280	1,280	2,823	1,280	1,150
	notional value of SOX reductions ($m)	12.37	10.24	10.24	22.61	0.00	0.00
	net NOX reduced (t/yr)	360	450	540	658	210	340

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1.0 INTRODUCTION AND INTERIM REPORT FINDINGS 1

1.1 INTRODUCTION 1

1.2 REPORT FINDINGS 2
1.2.1 Use of Mine Return Air 3
1.2.2 Use of Mine Drainage Methane 4
1.2.3 Use of Mine Return Air Plus Mine Drainage Methane 6
1.2.4 MRA/MDM Duct Land Use and Environment Context 6
1.2.5 Interim Report Conclusions 7

2.0 BASIC DATA AND DEDUCTIONS - MRA UTILIZATION 8

2.1 MINE RETURN AIR - QUANTITIES AND QUALITIES 8

2.1.1 Security and Longevity of Supply 8
2.1.2 Long Term Flow Predictions 9

2.2 POWER PLANT DATA 11

2.3 SUMMARY OF FLOWS 15

3.0 MINE RETURN AIR CONVEYING - LINGAN MINE AND PHALEN MINE TO LINGAN POWER STATION 17

3.1 OPTIONS STUDIED 17

3.1.1 Duct Size 17
3.1.2 MRA System and Controls 19
3.1.3 Benefits/Costs MRA - 0.4% 22
3.1.4 Environmental Benefits of Using MRA 25

4.0 CONCLUSIONS - UTILIZATION OF MRA 27

5.0 SUPPLY AND USE OF MINE DRAINAGE METHANE 28

5.1 MINE DRAINAGE METHANE - QUANTITIES AND QUALITIES 29

5.2 POWER PLANT INTERFACE 30

5.3 MDM COMBUSTION TEST RESULTS 30

6.0 MDM TREATMENT AND DELIVERY SYSTEMS 33

6.1 MDM TREATMENT AND DELIVERY - SIMPLE COMPRESSOR SYSTEM 33

6.1.1 Gas Supply System Control 35
6.1.2 Compressor Building 35
6.1.3 NOx Reduction Due to MDM Reburning 36

6.2 MDM GAS CONCENTRATION SYSTEM 36

6.2.1 Pressure Swing Adsorption Process 37
6.2.2 NOx Reduction Due to Concentrated MDM Reburning 38

6.3 MINE DRAINAGE METHANE - COLLECTION AND SUPPLY - COST ESTIMATES 39

7.0 MDM/MRA INTEGRATED SYSTEM 45

7.1 MDM/MRA INTEGRATED SYSTEM - COST ESTIMATE . . . 46

8.0 MDM/MRA UTILIZATION - RECOMMENDED PROJECT 50

9.0 MRA DUCT - LAND USE AND ENVIRONMENTAL CONTEXT . . . 51

9.1 IMPACTS 51

9.1.1 Benefits or Positive Impacts 51
9.1.2 Costs or Negative Impacts 52

9.2 RELEVANT LEGISLATION 52

9.2.1 Federal Legislative Context 53
9.2.1.1 Environmental Assessment Review Process (EARP) 53
9.2.1.2 Canadian Environmental Protection Act (CEPA) 55
9.2.1.3 Other Federal Statutes 55
9.2.2 Provincial Legislative Context 55
9.2.2.1 Environmental Protection Act 56
9.2.2.2 Environmental Assessment Act 57
9.2.2.3 Pipeline Act 58
9.2.2.4 Dangerous Goods and Hazardous Wastes Management Act 59
9.2.2.5 Private Ways Act 60

9.2.2.6 Other Provincial Legislation 60

9.3 RELATED MATTERS 61

9.3.1 Rights of Way 61
9.3.2 Liability in Respect to Nuisance 62

9.4 ACTIONS ARISING FROM ENVIRONMENTAL LEGISLATION 62

9.4.1 Assessment 63
9.4.2 Approvals/Permits 63

9.5 CONCLUSIONS - MRA DUCT - LAND USE AND ENVIRONMENTAL 64

10. REFERENCES 65

1.0 INTRODUCTION AND INTERIM REPORT FINDINGS

1.1 INTRODUCTION

The Committee on Atlantic Coal has commissioned Fenco Shawinigan Engineering Limited to undertake a study, for which this document is an interim report. The over-all objective of the study is to determine the most attractive way of utilizing two sources of methane which emanate from CBDC coal mining operations at Lingan and Phalen Mines.

The first source of methane is in the ventilation air which is used primarily to purge the mine workings of methane which escapes from the coal as it is being mined. A large fan induces air down through the mine and back to the surface where it is discharged to atmosphere as Mine Return Air (MRA). At this point it contains 0.4 - 0.6% methane. Both mines operate using this technique and their ventilation fans are within 2.8 km of Lingan power plant. There is potential financial benefit to be derived from conveying the MRA from the two mines and using it as combustion air in the boilers at Lingan Generating Station.

The benefits to the environment are:

- a reduction of methane to the atmosphere where it contributes to the "greenhouse effect";
- a reduction in sulphur dioxide emissions at the Generating Station due to the methane displacing some of the coal which contains sulphur;
- a reduction in nitrogenous oxides again as a result of displacing some of the coal.

The second source of methane comes from a system of suction pipework driven into the rock strata forming the roof above the coal seam. As the coal is removed and the roof collapses, methane collects in the strata from where the suction pipes tend to withdraw it. The suction pipework leads to vacuum pumps at the mine surface works, and these discharge the methane at concentrations of about 50% methane and 50% air, to atmosphere.

Various uses for this Mine Drainage Methane (MDM) have been explored including power generation at the mine [Ref. 2]. This study looks at two options. The first is to explore its potential as a "reburn" fuel. The second is to dump the gas into the MRA conveying duct and increase the MRA methane concentration slightly.

The first option has potential environmental benefits above and beyond those of methane in MRA. As a reburn fuel it can have the effect of reducing nitrogenous oxide (NO_x) emissions to a greater extent than just as a displacement fuel. The question to be resolved in this study is whether the improvement in NO_x emissions is worth the expense of compressing and delivering the gas to the generating station, plus modifying the boilers to accept the reburn fuel. A further sub-option to be explored is the possibility of separating the methane from the air and supplying a gas at close to 100% methane.

It should be noted that improving the methane concentration in MRA from 0.4 - 0.6% to some higher figure would be very expensive. It has not been considered as a viable option in this study.

1.2 REPORT FINDINGS

This Interim Report deals with the supply and potential use of Mine Return Air (MRA) with methane concentrations 0.4 - 0.6%, and the supply and potential use of Mine Drainage Methane (MDM) with concentrations 45 - 60% methane in air. The use of MRA (0.4%) is shown to be reasonably attractive, therefore consideration of the use of MDM is that it would be in addition to the MRA project. This is important because most of the benefits of using MDM can be achieved very cheaply by blending MDM with MRA at Lingan. In the analyses which follow, only the incremental benefits of delivering MDM to the Generating Station are considered i.e., improved NO_X reduction. These are weighed against the capital and operating costs.

1.2.1 Use of Mine Return Air

The study shows that the findings of a 1983 study [Ref. 1] on this option are still valid. Ducts of about 3.4 m diameter would feed from Lingan mine and Phalen mine ventilation fans, to a common 4.8 m diameter duct. This large ducts would follow routes yet to be defined in Phase II of this study. There are at least three plausible routes which are currently (July 1990) being explored. These include the route proposed in 1983 plus a route immediately north of NSPC ash lagoon, and the third route, south of NSPC ash lagoon. The interface with the Lingan Generating Station would be similar to that described in the 1983 study. That is to say, a suction fan adjacent to the main boiler house building feeding to a duct high on the building with delivery spouts to each of the four boiler forced draft fan intakes.

Preliminary cost estimates indicate direct capital costs of about $13.6 million plus indirect costs such as engineering, interest during construction and owners costs, for a further $7.1 million. Operating and maintenance costs $715,000/year.

The financial benefits based on coal displaced, and an average methane concentration of 0.4%, are $3.15 million/year. The net present value of costs and benefits based on a service life of 20 years, interest at 10.25% and inflation 5%/year, is:

PV costs	$28.78 million
PV benefits	$35.61 million
NPV	$ 6.83 million

A notional value of the displacement of sulphur dioxide (SO_2) can be used to further enhance the project. NSPC [Ref 4] has suggested a figure of \$400/tonne of SO_2 avoided is reasonable based on the findings of recent studies of SO_2 removal/avoidance systems. The MRA at 0.4% methane will reduce SO_2 emissions by about 2700 tonnes/year. Therefore, a further benefit of net present value \$21.64 million could be attributed to this project.

The other environmental benefits of avoiding methane and NO_X emissions to the atmosphere have been evaluated on a non financial basis. The reduction in NO_X is about 330 tonnes/year, which is a minor amount compared with what can be achieved by some boiler retrofit technologies.

Emitting the methane contained in Lingan/Phalen MRA (0.4%) exhausted to the atmosphere each year is equivalent in greenhouse effect, to the Carbon Dioxide emitted from a 300 MW thermal power plant operating for a year. Thus, the reduction achievable by using MRA as combustion air is not insignificant.

1.2.2 Use of Mine Drainage Methane

A series of combustion tests were conducted at CANMET Laboratories [Ref. 5] June/July 1990 which showed that by using MDM in a single boiler, the NO_X on that boiler could be reduced by about 15%. The MDM would actually displace about 8% of the coal fuel. If the MDM were treated to remove its air content and deliver near 100% methane, the NO_X levels could be reduced by about 20%.

NSPC provided figures for NO_X emissions [Ref. 6] at full load which are between 400 and 450 ppm vd. They indicated that developments in burner technology, over fire air, and boiler operation optimization could reduce these figures to less than 300 ppm vd. i.e. 25-30% reduction.

By using information on MDM compression and delivery systems, developed in a 1988 study for CBDC, [Ref. 2] preliminary cost estimates were made of an MDM delivery system to Lingan Generating Station. The direct capital costs are \$2.60 million, indirect costs \$1.43 million for a total \$4.03 million. Operations and maintenance costs are estimated at \$313,000/year. The net present value of these costs is estimated at \$7.57 million.

The benefits of using MDM in this way, as compared with combining it with MRA and using it as combustion air, are the incremental amounts of NO_X reduction. Thus, if methane is used as a fuel at say, 8% of the total, then NO_X emissions are likely to reduce by about 8% due to reduction in coal burnt, and the fuel bound nitrogen which is a major contributor to NO_x. Therefore the re-burning technique benefits are the amounts in excess of 8% reduction. In the case of MDM as a reburn fuel the total benefit is 15% NO_x reduction and the net is 7%. This 7% equates to about 210 tonnes/year at a life cycle - 20 year cost of \$1801/tonne (1990).

By using 100% methane instead of MDM (50% methane) the NO_X reduction would increase to 20% for a net amount of 12% (360 tonnes/year).

The concentration of methane in MDM can be increased from 50% to 95% by a "Pressure Swing Adsorption" process (PSA). The quantity of methane would reduce by about 10% because of losses from the PSA process so that the net benefit now would be 360-36 = 324 tonnes/year. The direct capital cost of a PSA system and methane delivery system would be \$3.59 million plus indirect costs \$1.97 million for a total \$5.56 million. The annual operating and maintenance costs are estimated at \$515,000/year. The net present value of these costs is estimated at \$11.38 million.

The MDM, concentrated to 95% methane displaces 324 tonnes/year of NO_X at a life cycle - 20 year cost of \$1756/tonne (1990).

NSPC has indicated at a progress meeting July 1990, that these costs are not encouraging. Other technologies are known which can achieve a reduction in NO_X at less cost/tonne. Based on that understanding, a decision was made that the balance of this study would focus on blending MDM with MRA at Lingan, and conveying MRA from both Lingan and Phalen mines for use as combustion air at Lingan Generating Station.

1.2.3 Use of Mine Return Air Plus Mine Drainage Methane

At Lingan Mine, the MRA fan and the MDM extraction system are within a hundred metres of each other. It is envisaged that a pipe will be run from the MDM to the MRA system where the MDM will be blended with the MRA. The cost of the pipework together with the protective controls and devices necessary to avoid explosive mixtures, will be less than $500,000. The MRA system will be as described in section 1.2.1. The total direct capital costs will be $14.10 million, indirect costs will be $7.3 million, operating and maintenance costs will be $526,000/year. The net present value of these costs is $29.19 million, and the benefits in terms of saving 70,000 tonnes of coal/year, are $65.11 million. Thus the net benefit is $35.92 million.

1.2.4 MRA/MDM Duct Land Use and Environment Context

A preliminary investigation of federal, provincial and local regulations has identified no significant regulatory impediment to the proposed project. There are legislative requirements for review of the project which should lead to the granting of permits.

Although no regulations specifically focus on the aesthetic or visual impact of the project this issue may be raised. To the extent possible, the routing should be kept at some distance from the public highway. Alternatively the duct should be buried or partially buried.

The increased cost of full burial of the duct is likely to be several million dollars. Thus it should only be considered after a detailed assessment of the project viability. This assessment may include the notional monetary value for reducing SO_2 emissions. This would increase the value of benefits by a further $39.6 million net present value.

1.2.5 Interim Report Conclusions

This report concludes Phase I of the study. The objective of Phase I was to review a number of options and identify a single option for more detailed study in Phase II of the study.

There is a very clear indication that a single project has been identified, and that it has the potential for very positive viability both in financial terms, and its benefits to the environment. The project will be a duct to convey MRA from both Lingan and Phalen mines, plus a system to blend MDM in with the MRA from Lingan mine. The enriched MRA at about 0.8% methane content will be used as combustion air at Lingan Generating Station.

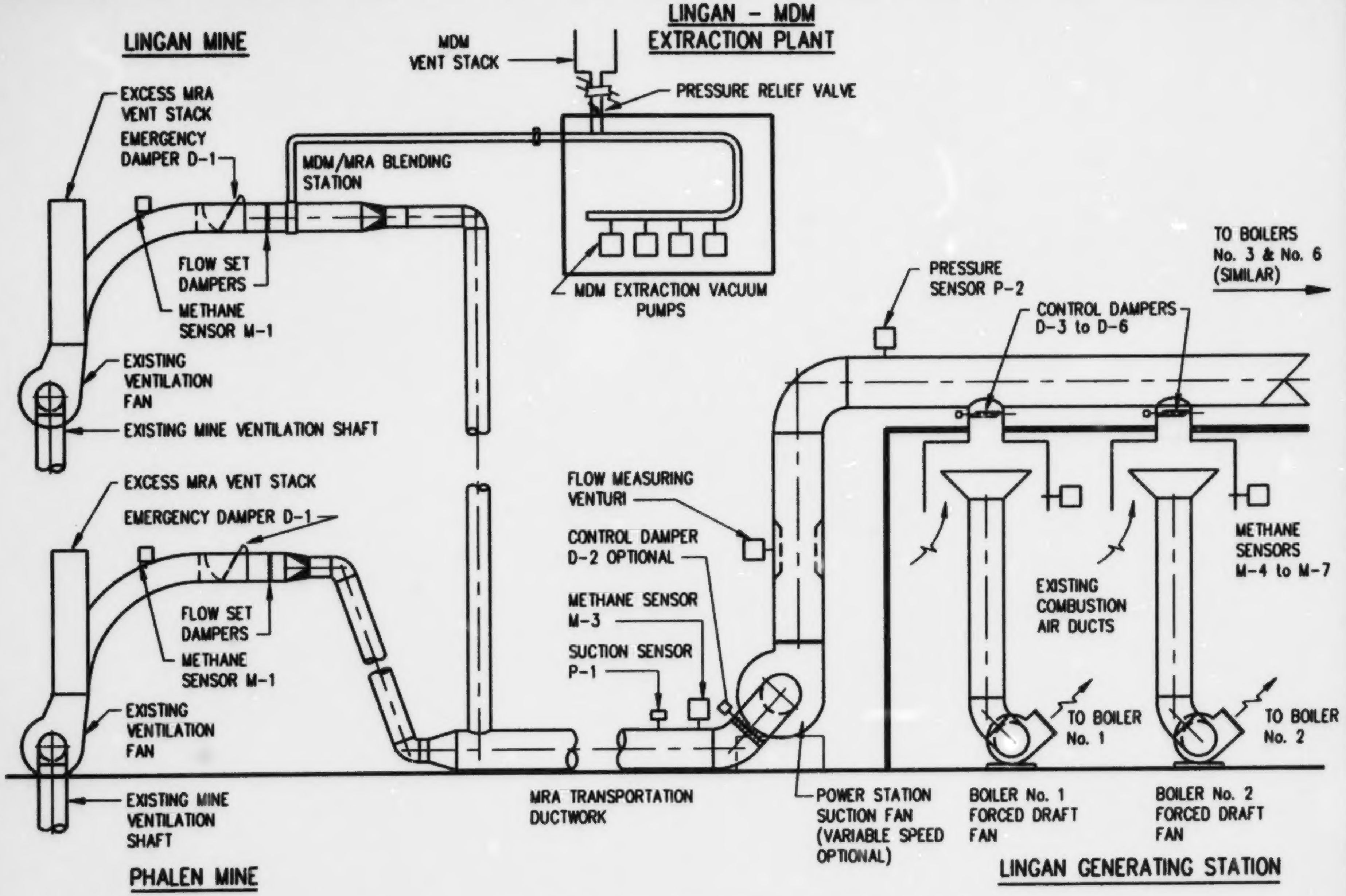

LINGAN MINE
EXCESS MRA VENT STACK
EMERGENCY DAMPER D-1
FLOW SET DAMPERS
METHANE SENSOR M-1
EXISTING VENTILATION FAN
EXISTING MINE VENTILATION SHAFT
MDM/MRA BLENDING STATION
MDM VENT STACK
LINGAN - MDM EXTRACTION PLANT
PRESSURE RELIEF VALVE
MDM EXTRACTION VACUUM PUMPS
EXCESS MRA VENT STACK
EMERGENCY DAMPER D-1
FLOW SET DAMPERS
METHANE SENSOR M-1
EXISTING VENTILATION FAN
EXISTING MINE VENTILATION SHAFT
PHALEN MINE
MRA TRANSPORTATION DUCTWORK
FLOW MEASURING VENTURI
CONTROL DAMPER D-2 OPTIONAL
METHANE SENSOR M-3
SUCTION SENSOR P-1
POWER STATION SUCTION FAN (VARIABLE SPEED OPTIONAL)
PRESSURE SENSOR P-2
CONTROL DAMPERS D-3 to D-6
TO BOILERS No. 3 & No. 6 (SIMILAR)
EXISTING COMBUSTION AIR DUCTS
METHANE SENSORS M-4 to M-7
TO BOILER No. 1
TO BOILER No. 2
BOILER No. 1 FORCED DRAFT FAN
BOILER No. 2 FORCED DRAFT FAN
LINGAN GENERATING STATION

FIGURE 1.1 UTILIZATION OF MINE RETURN AIR AND MINE DRAINAGE METHANE CONCEPT SCHEMATIC

2.0 BASIC DATA AND DEDUCTIONS - MRA UTILIZATION

2.1 MINE RETURN AIR - QUANTITIES AND QUALITIES

Cape Breton Development Corporation (CBDC) undertook to provide information to the study team. The following text is based on a CBDC letter, April 25, 1990, to the Study Technical Steering Committee [Ref. 3]. The word "methane", as used here, means a mixture of aliphatic hydrocarbons made up of 95% methane and diminishing amounts of higher weight gases. Figure 2.1 and 2.2 are records of the methane content of MRA in April 1987 as measured at Lingan Colliery.

Spot checks on the MRA temperature throughout the year, from the two mines, are indicative of what may be found when continuous data are obtained. The table below contains the available data.

Month (1989/1990)	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Lingan °C	18	18	—	18	14	17	16	17	16
Phalen °C	14	14	12	10	10	10	10	11	11

Note: Lingan MRA is warmer due to:

- deeper mining;
- longer ventilation paths;
- more underground motors and equipment.

2.1.1 Security and Longevity of Supply

The coal reserves at both Lingan and Phalen collieries are sufficient for many decades of mining activity at present rates of extraction. Limiting

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT: LINGAN METHANE STUDY

T.O.BY: P.J. MAHON
PRICED BY: P.J. MAHON
DATE: DEC 10, 1990
SHEET 2 OF 8

JOB NO. 58613
CLIENT COM. ON ATLANTIC COAL
TYPE OF ESTIMATE STUDY
CKD. BY:

ACCT.	DESCRIPTION	QUANTITY	UNIT	COST OR M/HRS PRE UNIT MATL	COST OR M/HRS PRE UNIT M/H	COST OR M/HRS PRE UNIT LABS	MATERIAL COST	SUBCONTRACT M/HRS	SUBCONTRACT DOLLARS	LABOUR M/HRS	LABOUR DOLLARS	TOTAL DOLLARS
	WBS AREA 2 SUBCODE 28 MECHANICAL											
	PHALEN, CONNECTION FROM MINE FAN TO MAIN SUCTION DUCT.											
286	RECTANGULAR DUCT, (4.5m × 4.1 m × 23 m) 10mm thick A-36 STEEL c/w STIFFENERS, FLANGES	30,000	Kg	3.00			90,000				62,000	
286	DUCT INSULATION FOR 4.5m × 4.1m × 20 m DUCT. POLYURETHANE 25 mm. thick.	212	M²	20.00			4,200				INCL.	
286	EMERGENCY DAMPER FABRICATED A-36 STEEL ASSEMBLY	1	EA.				24,000				12,000	
286	AIR INLET & SHUTOFF DAMPER (4.3m × 2.4m.) 10 GAUGE G.S. AIRFOIL BLADES	2	EA.				62,000				10,000	
286	EXCESS MRA VENT "STACK" (4.3m × 2.4m 3 m) 10mm. thick c/w STIFFENERS, FLANGES A-36 STEEL	3,900	Kg	3.00			12,000				19,000	
286	LOW POINT DRAIN ASSEMBLY.	1	EA.				2,800				2,000	
286	DUCTWORK SUPPORTS, STEEL AND CONCRETE						60,000				INCL.	
	SUB TOTAL THIS PAGE						255,000				105,000	360,000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT: LINGAN METHANE STUDY

T.O. BY: P.J MAHON
PRICED BY: P.J. MAHON
DATE: DEC 10, 1990
SHEET 3 OF 8
JOB NO. 58613
CLIENT COMM. ON ATL. COAL
TYPE OF ESTIMATE STUDY
CKD. BY:

ACCT.	DESCRIPTION	QUANTITY	UNIT	COST OR M/HRS PER UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
				MATL	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
	WBS AREA 2 SUBCODE 28 MECHANICAL											
				$								
	LINGAN, CONNECTION FROM MINE FAN TO MAIN SUCTION DUCT.											
286	RECTANGULAR DUCT (4.3m × 2.4m × 15 m) 10mm. thick A-36 STEEL c/w STIFFENERS, FLANGES	15,000	Kg	3.00			45,000				33,000	
286	DUCT INSULATION FOR 4.3m × 2.4m × 20m DUCT POLYURETHANE 25mm. thick.	134	m^2	20.00			2,680				INCL.	
286	EXCESS MRA VENT "STACK" (4.3m × 2.4m × 6 m) 10mm thick. A-36 STEEL c/w STIFFENERS, FLANGES	6,000	Kg	3.00			18,000				13,000	
286	EMERGENCY DAMPER FABRICATED A-36 STEEL ASSEMBLY	1	EA				18,000				13,000	
286	SHUTOFF & AIR INLET DAMPERS FOR EMERGENCY DAMPER ASSY	2	EA	31,000			62,000				10,000	
286	FLOW SET DAMPER (4.3m × 2.4m.) 10 GAUGE C.S. AIRFOIL BLADES	1	EA				31,000				2,000	
286	LOW POINT WATER DRAIN ASSEMBLY	1	EA				2,370				2,000	
286	SUPPORTS, STEEL & CONCRETE						60,000				INCL.	
	SUBTOTAL THIS PAGE						239,000				73,000	312,000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT: Lingan Methane Study

T.O.BY: P.J. Mahon PRICED BY: P.J. Mahon DATE: Dec10, 1990 SHEET 4 OF 8
JOB NO. 58617 CLIENT Comm. on Atlantic Coal TYPE OF ESTIMATE Study CKD. BY:
DESCRIPTION WBS Area 2 Subcode 78 Mechanical

ACCT.	DESCRIPTION	QUANTITY	UNIT	COST OR M/HRS PRE UNIT MATL	M/H	LABS	MATERIAL COST	SUBCONTRACT M/HRS	SUBCONTRACT DOLLARS	LABOUR M/HRS	LABOUR DOLLARS	TOTAL DOLLARS
	MDM Injection/Mixing											
287	Mixing Duct 4.0m. Dia. x 3m. Long x 10mm. thick	2835	KG	2.50			7090				2,000	
	A-36 Steel Rolled Steel c/w Stiffeners & Flanges.											
287	Fabricated Explosion Panels In Duct Section	4725	KG	2.50			11,800				4,000	
	A-36 Steel 4.0m. Dia. x 5m. Long.											
287	Pipe 12" A-106 C.S. Std. Wt.	20	m	105			2100				3150	
287	Elbow 12" 90° A234 WCB Std Wt.	3	EA.	250			750				1440	
287	Flange 12" A-105 Class 150 Std Wt.	14	EA.	170			2380				5040	
287	Flange 12" Blind A-105 Class 150	4	EA	210			840				480	
287	Valve 12" High Perf. Butterfly Wafer.	1	EA	3200			3200				480	
287	Tee 12" A234 WCB Std Wt.	1	EA	490			490				960	
287	Reducer 12"x8" A234 WCB Std Wt.	2	EA	110			220				800	
287	Elbow 8"-90° A234 WCB Std. Wt.	3	EA	105			315				960	
287	Flange 8" - A105 Class 150 Std Wt.	6	EA	80			480				1440	
287	Pipe 8" - A106 Std. Wt.	20	m.	60			1200				420	
287	Pipe Cap 8" A234 WCB Std Wt.	2	EA.	35			70				640	
287	Misc. Piping Specialties	1	LOT				4,000				2290	
287	Misc. Steel Pipe Supports	1	LOT				3065				1900	
	Subtotal This Page						38,000				26,000	64,000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT: LINGAN METHANE STUDY

T.O.BY: PJ MAHON
PRICED BY: P.J. MAHON
DATE: DEC 10, 1990
SHEET 5 OF 8
JOB NO. 58617
CLIENT COMM. ON ATL COAL
TYPE OF ESTIMATE STUDY
CKD. BY:

ACCT.	DESCRIPTION	QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
				MATL	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
	WBS AREA 3 SUBCODE 31 MECHANICAL											
31	MRA FAN, CENTRIFUGAL 600 RPM DWDI	1	EA				276,000				60,000	336,000
	380m³/s, 3240 Pa.											
31	FAN LUBE OIL COOLING (AIR TO OIL)	1	LOT				17,000			INCLUDED IN FAN		
31	FAN COUPLING	1	EA.				5,000				DITTO.	
31	FAN BRAKE (MANUAL)	1	EA.				2,000				DITTO.	
31	FAN INLET BOX	1	EA.									
31	VARIABLE INLET VANES	2	EA.	26,000			52,000				DITTO.	
31	VARIABLE INLET VANE ACTUATOR	2	EA.				INCL IN INSTRUMENTATION WORKSHEET					
31	FAN MOTOR 2250 H.P. (1677 kW)	1	EA.				309,000				DITTO.	
31	FAN OUTLET EVASE 4.4m × 6m HI × 7.4m	1	EA.				30,000				DITTO	
31	SPECIALTY ITEMS	1	LOT				79,000				30,000	
	SUBTOTAL THIS PAGE						761,000				90,000	851,000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT: LINGAN METHANE STUDY.

T.O.BY:	J MAHON	PRICED BY:	J MAHON				DATE:	DEC 10, 1990			SHEET 6 OF 8	
JOB NO.	58613	CLIENT COMM. ON	ATLANTIC COAL	TYPE OF ESTIMATE			STUDY			CKD. BY:		
DECRIPTION		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
ACCT.	WBS AREA 3 SUBCODE 32 MECHANICAL			MATL	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
32.	INLET PLENUMS TOTAL #4, A-36 STEEL	130,000	kg	3.00			390,000				290,000	
32	MRA SHUTOFF DAMPER 3m.x3m. c/w ACTUATOR	4	EA	21,078			84,312		DAMPER INSTALLATION IN PLENUM COST.			
32	MRA CONTROL DAMPER 3mx3m. c/w ACTUATOR	4	EA	21,783			87,132				DITTO	
32	AIR BACKDRAFT DAMPER	4	EA	11,396			45,584				DITTO	
32	AIR SUPPLY PIPING TO DAMPERS PIPING & FITTINGS (1" DIA)	1	LOT.				2972				3,000	
32	GRAVITY RELIEF DAMPER	1	EA				35,000				5,000	
	SUBTOTAL THIS PAGE						645,000				298,000	943,000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT:

T.O.BY: P. Adams
PRICED BY: P. Adams
DATE: Dec 20, 96
SHEET 7 OF 8
JOB NO. 58613
CLIENT Comm on Air Coal
TYPE OF ESTIMATE Study
CKD. BY:

DECRIPTION		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
ACCT.	WBS Area 2 Subcode 21 · 1			MATL	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
214	Ductwork 4.8m Dia.											
214	Ductwork 4.4m x 4.4m.											
214	Steel Supports											
214.	Concrete Foundations.											
	Subtotal.						1,907,000				1,557,000	3,464,000
211	Boilerhouse Modifications (Roofing, Cladding, Etc)	Lump Sum										350,000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT:

T.O.BY: P.J. Mahon PRICED BY: P.J. Mahon DATE: Dec 10, 1990 SHEET 8 OF 8

JOB NO. 58613 CLIENT Comm. on Atlantic Coal TYPE OF ESTIMATE Study CKD. BY:

DESCRIPTION		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR		TOTAL DOLLARS
ACCT.	WBS AREA 7 SUBCODE 73 MECHANICAL			MATL	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
731	PLANT VENTILATION FAN, 45m³/s, 500 Pa.	4	EA.	14,000			56,000				70,000	
721	LOUVRE FOR VENTILATION FAN OUTLET	4	EA.	6,500			26,000				8,000	
	4.0m. x4.0m.											
731	STEEL DUCTWORK, FAN TO LOUVRE CONNECTIONS	8,500	Kg	3.9			33,000				13,000	
	8 GAUGE GALVANIZED											
731	MISC. SUPPORT STEEL	2,000	Kg	3.00			6,000				5,000	
	SUBTOTAL THIS PAGE						121,000				96,000	217,000

FENCO SHAWINIGAN ENGINEERING
(1985) LIMITED

ESTIMATE WORKSHEET

PROJECT:

T.O. BY:
PRICED BY: P. ADAMS.
DATE:
SHEET 1 OF 1
JOB NO. 58613
CLIENT
TYPE OF ESTIMATE BUDGETARY
CKD. BY:

DESCRIPTION		QUANTITY	UNIT	COST OR M/HRS PRE UNIT			MATERIAL COST	SUBCONTRACT		LABOUR & EQUIP		TOTAL DOLLARS
ACCT.				MAT'L	M/H	LABS		M/HRS	DOLLARS	M/HRS	DOLLARS	
1	SITE											
116	SITE PREP. (INCL. MOBILIZATION)		LS									500,000
2	STRUCTURES											
28	TRANSMISSION DUCT											
284	INSULATION SUPPLY & INSTALL	45,000	SM				22^{00}					990,000
281	TRANSMISSION DUCT: SUPPLY 4800⌀ CSP DUCT w/LINER	1600	LM				1690^{00}					2,704,000
	SUPPLY 4000⌀ CSP DUCT w/LINER	930	LM				1505^{00}					1,399,650
	SUPPLY REDUCER	1	EA				$10,000^{00}$					10,000
	SUPPLY WYE	1	EA				$10,000^{00}$					10,000
	SUPPLY 4000⌀ MULTI-FL BREECHING	20	LM				2000^{00}					40,000
	SUPPLY BENDS	2	EA				$10,000^{00}$					20,000
	ERECT DUCT & FITTINGS	2550	LM								215^{00}	548,250
282	STRUCTURAL SUPPORTS: SUPPLY FOUNDATIONS	380	EA				7520^{00}					2,857,600
282	INSTALL FOUNDATIONS	380	EA								500^{00}	190,000
283	SUPPLY COLUMNS	2600	LM				510^{00}					1,326,000
	ERECT COLUMNS	380	EA								250^{00}	95,000
	SUPPLY 4800⌀ DUCT CRADLES	112	EA				6280^{00}					703,360
	SUPPLY 4000⌀ DUCT CRADLES	68	EA				4310^{00}					293,080
	ERECT DUCT CRADLES	180	EA								750^{00}	135,000
												11,821,940

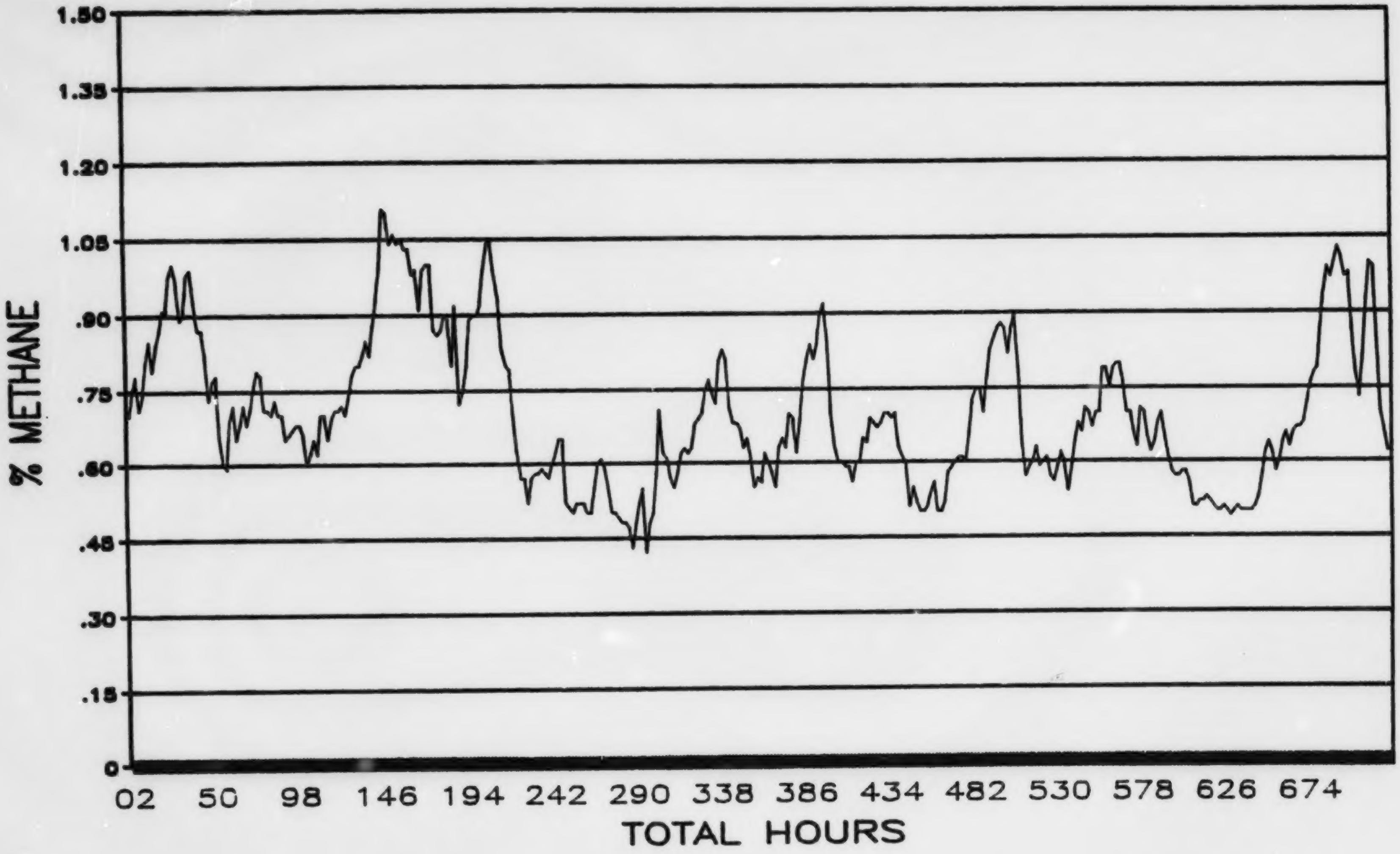


FIGURE 2.1 METHANE CONTENT OF MINE RETURN AIR

LINGAN COLLIERY

APRIL 1987

(TWO HOUR INTERVALS)

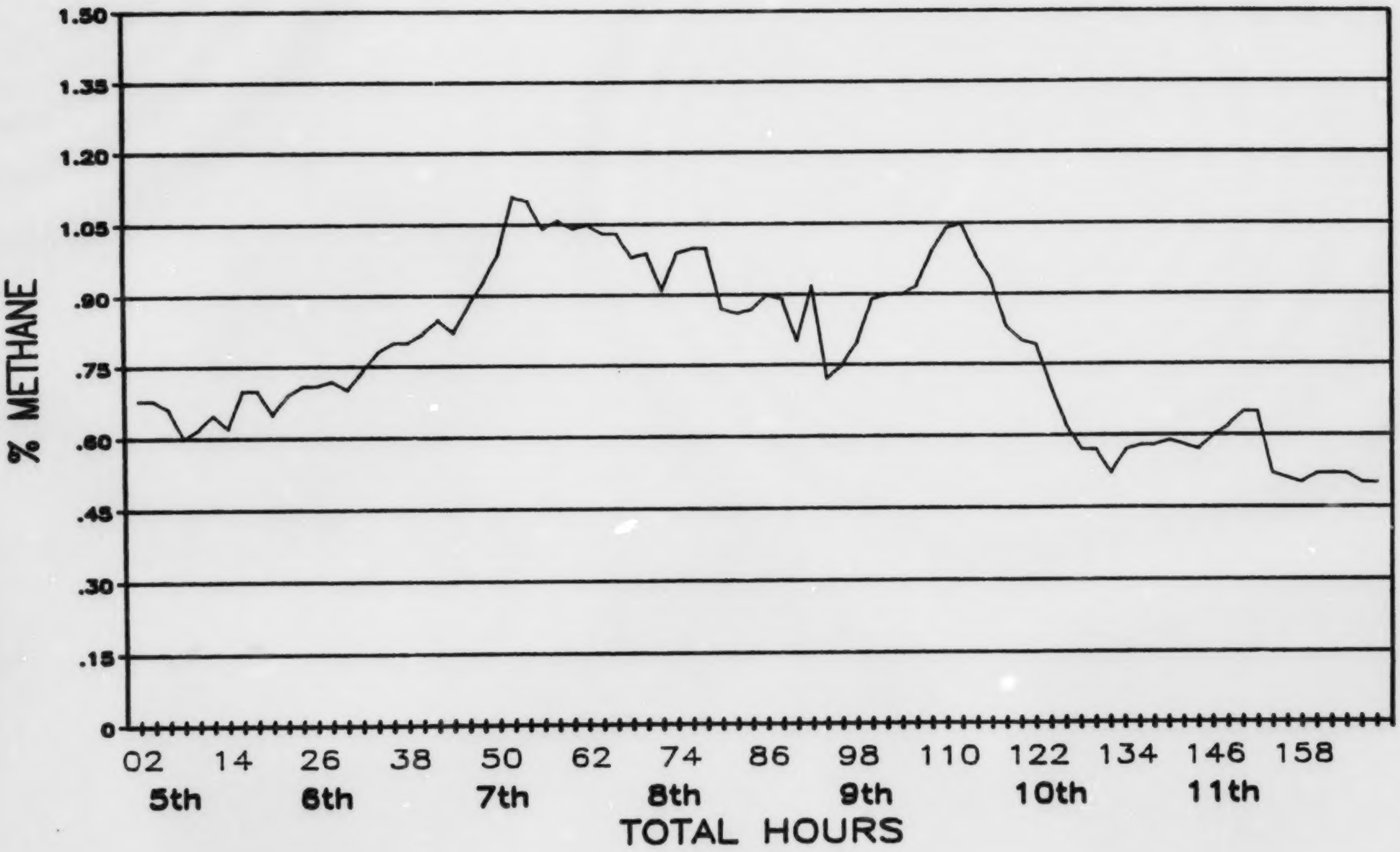


FIGURE 2.2 METHANE CONTENT OF MINE RETURN AIR

LINGAN COLLIERY

APRIL 5th to 11th, 1987
(TWO HOUR INTERVALS)

conditions are more imposed by distances from the mine entrance as workings move farther seaward. Other limits may be imposed by strata pressure as the depth of mining increases. However these factors are not expected to limit production over the next ten years.

The Federal Minister responsible for CBDC (Tom Hockin) has publicly restated that Lingan Mine must meet production targets in order to ensure continued government funding. These targets are not being met right now, so there is serious concern that the mine could be closed. Notwithstanding this possibility, present mining plans are such that methane flows as outlined in the following paragraphs will be sustained for at least 10 years as stated in the CBDC letter. This study assumes that the flows are good for 20 years. This assumption must be re-examined in Phase II.

2.1.2 Long Term Flow Predictions

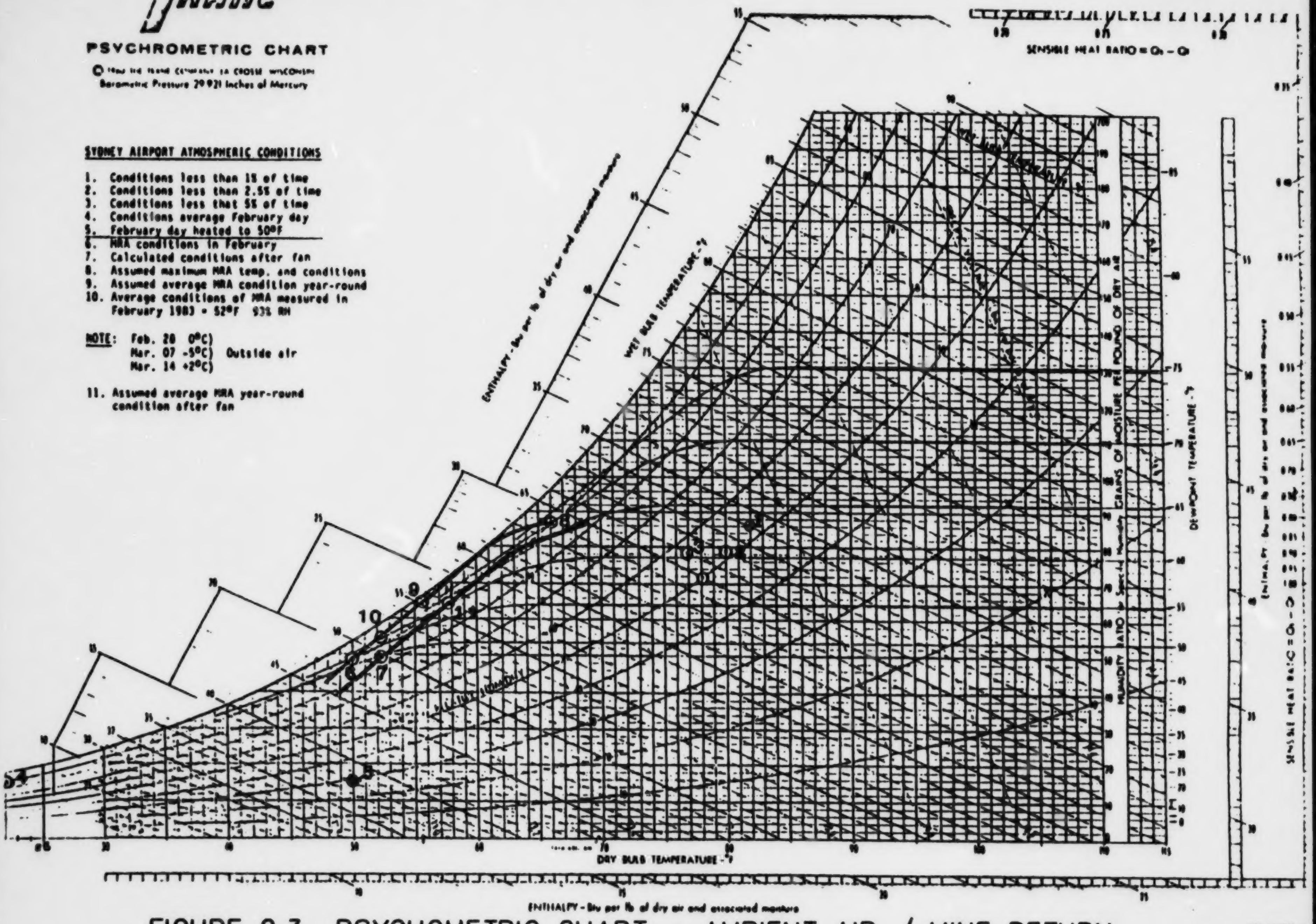
Lingan Colliery, over the next two years, plans to convert to a retreat mining system, with somewhat reduced total coal output compared to present rates. It has a Mine Drainage Methane (MDM) system which will continue to operate, and is described in more detail in Section 5 of this report. It currently abstracts about 0.5 m^3/s of methane mixed with an equal amount of air. This flow is expected to be maintained over the next ten years. Ventilation air flow (MRA) is expected to be maintained at current levels of 165 m^3/s. Methane content is forecast to remain roughly constant at 0.4%.

Phalen ventilation air flow (MRA) is currently at 170 m^3/s and is expected to remain at this magnitude for the near future. Air flow rates and patterns are being changed to suit underground conditions. However, as the mined out area expands, it is expected that MRA flows will slowly increase. (Installed fan ventilation capacity is in excess of 300 m^3/s). Current methane content is 0.6% and is expected to remain at this concentration until the installation of a methane drainage system. Even with very high cutting rates on the retreat walls there appears to be no immediate need for it. However, in the next three years further changes in mining methods are planned which will likely make methane drainage a necessity. A number of factors make estimation of the MDM extraction rate imprecise. A reasonable value to use at this time is 50% of the total methane or 0.5 m^3/s. For the purpose of this Interim Report, it is assumed that the MDM system will be in place, and that the MRA characteristics will be the same as at Lingan.

The levels of MRA temperature and humidity were recorded in February, 1983, from a series of readings which were observed over a period of three weeks. It is surmised that in winter, the outside ambient temperatures and humidities are such that, after passing through the mine, the return air is less than saturated, and at temperatures approaching 10°C (50°F).

Figure 2.3 - Psychometric Chart: Ambient Air/Mine Return Air - is a prediction of annual conditions based on the readings taken in February/March, 1983, and records of climate at Sydney Airport. Two lines plotted on the chart show the expected range of conditions of the MRA immediately before, and after the mine fan. It should be noted that the heating effect of these fans is beneficial towards reducing condensation in the duct. The insulation levels called for in the duct design will be sufficient to minimize condensation under all of the conditions plotted.

From the above reasoning, the average annual condition of MRA before the mine fan (Point #9 on the chart) is 12.8°C (55°F) and 98% relative humidity. The calculation of MRA conditions arriving at the power station are based on these figures. The quantities are as follows:



SYDNEY AIRPORT ATMOSPHERIC CONDITIONS

1. Conditions less than 1% of time
2. Conditions less than 2.5% of time
3. Conditions less that 5% of time
4. Conditions average February day
5. February day heated to 50°F

---

6. MRA conditions in February
7. Calculated conditions after fan
8. Assumed maximum MRA temp. and conditions
9. Assumed average MRA condition year-round
10. Average conditions of MRA measured in February 1983 = 52°F 93% RH

NOTE: Feb. 28 0°C)
Mar. 07 -5°C) Outside air
Mar. 14 +2°C)

11. Assumed average MRA year-round condition after fan

FIGURE 2.3 PSYCHOMETRIC CHART – AMBIENT AIR / MINE RETURN

MRA from Lingan at 0.4% Methane

Dry Air	161.85 m^3/s
Moisture	2.48 m^3/s
Methane	0.67 m^3/s
Total	165.00 m^3/s

MRA from Phalen at 0.4% Methane

	Current	Max.
Dry Air	166.75 m^3/s	294.27 m^3/s
Moisture	2.56 m^3/s	4.53 m^3/s
Methane	0.69 m^3/s	1.20 m^3/s
Total	170.00 m^3/s	300.00 m^3/s

2.2 POWER PLANT DATA

Lingan Generating Station comprises four almost identical units. Nova Scotia Power Corporation (NSPC) kindly made available in the 1983 report [Ref. 1] the boiler performance data which the boiler manufacturer had submitted with their equipment supply tender. The figures below are abstracted from that data sheet. It should be noted that the full load figure for the boiler was at that time 168 MW. The actual turbines installed are rated at 150 MW; however, the difference does not materially affect the calculation of the performance when methane is included in the combustion air.

Boiler Performance at Maximum Load

Steam Leaving Superheater	Mlb/h	1,080
Steam Leaving Reheater	Mlb/h	958
Excess Air Leaving Economizer	%	18
Quantity of Fuel	Mlb/h	125.5
Flue Gas	Mlb/h	1,611
Air	Mlb/h	1,383

	Continuous Blowdown	Mlb/h	5.4
Pressure;	Steam Leaving Superheater	psig	1,852
	Steam Entering Reheater	psig	519
	Steam Leaving Reheater	psig	499
Temp;	Steam Leaving Superheater	°F	1,005
	Steam Entering Reheater	°F	694
	Steam Leaving Reheater	°F	1,005
	Gas Leaving Economizer	°F	701
	Gas Leaving Air Heater	°F	343/322
	Water Entering Economizer	°F	471
	Water Leaving Economizer	°F	539
	Air Entering Heater	°F	80
	Air Leaving Heater	°F	543
Heat Losses;	Dry Gas	%	5.87
	H_2 and H_2O in Fuel	%	4.57
	Moisture in Air	%	0.14
	Unburned Combustible	%	0.20
	Radiation	%	0.20
	Unaccounted for	%	1.50
	Boiler Efficiency	%	87.52

Fuel as Fired

Coal as defined in the contract specifications.

Proximate Analysis % by Weight

Moisture	7.5
Volatile Matter	31.4
Fixed Carbon	50.0
Ash	11.1

Total	100.0

Ultimate Analysis % by Weight (only one component was identified):

Sulphur	4.0 (max.)
Btu/lb	12,000

In order to develop calculations of combustion products when using either MRA or the existing boiler room air, it was necessary to assume an ultimate analysis typical of the specified coal. This was as follows:

	% by Weight
Carbon	67.4
Hydrogen	4.0
Sulphur	2.5
Oxygen	6.0
Nitrogen	1.5
Moisture	7.5
Ash	11.1
Total	100.0

Plant Operating Hours

Extrapolations from the 1983 study [Ref. 1] calculations of performance of the plant on MRA (0.4%) indicate that the total 335 m^3/s supply of MRA would satisfy the combustion air requirements for 396 MW of power generation. In order to ensure minimum ventilation of the boiler spaces, some boiler room air must be drawn into the boiler. Accordingly, a figure of 500 MW is assumed as the minimum load for 335 m^3/s MRA (0.4%) utilization. On this basis, at generating production equal to, or less than, 100 MW, all combustion air is extracted exclusively from the boiler room, and no MRA is utilized. At generating production above 100 MW, an increasing amount of MRA is utilized to supplement combustion air. The maximum MRA which could be used is for the full plant output - 600 MW, less 100 MW to ensure some ventilation, i.e. 500 MW. This equates to about 400 m^3/s of MRA which may become available when Phalen is further developed, and Lingan is at full production.

Information on the Lingan Generating Station future production, was provided verbally by NSPC (reference discussion Mr. M. Whelan, May 1990). The table below shows the forecast plant capacity factors for the next twenty years.

From this, the annual amounts of MRA in excess of plant requirements, can be calculated. These are based on 335 m^3/s for present MRA availability, and 400 m^3/s, which is the maximum acceptable flow.

Year	Capacity Factor %	% MRA in Excess of Requirements	
		Supplied at 335 m^3/s %	Supplied at 400 m^3/s %
1990 to 2000	80	3	20
2001 to 2005	75	8	25
2006 to 2010	65	18	35

In order to finalize the optimization of the duct, it will be necessary to have more firm predictions of the availability of MRA/MDM. Figures given so far are for a firm flow of 335 m^3/s of MRA for 10 years, yet a 20 year life of plant -Lingan Generating Station - is predicted. Mention is made of possible increases in flow from Phalen, but the future for Lingan is dependent upon continued government support.

It is known that even if a mine is closed, methane continues to be available. It is therefore conceivable that the Lingan MRA farm could be kept running, even though the mine is not operating. The decay of methane concentration, or the reduction in ventilation air (MRA) should be predicted.

2.3 SUMMARY OF FLOWS

		Now	Maxima
MRA	- Lingan	165 m^3/s	165 m^3/s
	- Phalen	170 m^3/s	300 m^3/s
		335 m^3/s	465 m^3/s

Power Plant Requirement - Up to 400 m^3/s MRA

	Now	Future
MDM - Lingan	0.5 m^3/s	0.5 m^3/s
MDM - Phalen	-	0.5 m^3/s
	0.5 m^3/s	1.0 m^3/s

Note: MDM flows are expressed in terms of methane only. There will be various amounts of entrained air of roughly equal quantities. The resultant methane concentration will be 50%.

3.0 MINE RETURN AIR CONVEYING - LINGAN MINE AND PHALEN MINE TO LINGAN POWER STATION

3.1 OPTIONS STUDIED

There are two configurations which can be considered. An independent duct for each mine's MRA, or a combined duct. The former calls for a more simple control system, while the latter affords a possible cost saving.

It should be noted that the 1983 study [Ref. 1] concluded that the best option was to construct a large diameter duct with a fan at Lingan Generating Station to transport the MRA three kilometres, and discharge it at the boiler FD fan inlets. Any form of compressor and pipeline proved to be more expensive and less energy efficient. Nothing has been noted since 1983 which would change that conclusion.

The same study reviewed various types of duct construction:

- corrugated steel pipe (CSP);
- cast-in-place concrete pipe;
- precast concrete pipe;
- fibreglass reinforced pipe; and
- welded steel pipe.

Cost estimates for 1983 showed a clear cost advantage by using CSP. Therefore for this preliminary part of the study it will be assumed as the choice in 1990. This will of course be confirmed during subsequent design study phases.

3.1.1 Duct Size

The 1983 study concluded that a duct of 3.6 m (12 ft.) would be optimal for the projected 450,000 cfm (212 m^3/s). The presently available quantities are

165 m^3/s for Lingan Colliery and 170 m^3/s for Phalen Colliery total 335 m^3/s, therefore, a larger duct is likely to be optimal in 1990.

A preliminary investigation was undertaken to determine a new optimal main duct size based on extrapolated data from the 1983 study. From such extrapolations, the table below shows the pertinent characteristics of the costs associated with various duct sizes for conveying 335 m^3/s MRA.

Duct Size m	Construction Cost $ Million 1990	Fan Power kW	Power Cost [Ref.7] $ m/yr	Maintenance Cost $ Million per year	NPV (20y) $ Million 1990
3	7.6	8900	4.06	0.228	56.07
3.6	9.1	3590	1.66	0.273	30.15
4.2	11.3	1056	0.755	0.339	23.67
4.8	13	812	0.370	0.390	21.59
5.6	14.53	500	0.228	0.436	22.04

It should be noted that the above Construction Costs do not include such elements as: land costs, and indirect costs such as engineering, financing and administration. Their exclusion does not affect the conclusion that the optimum main duct diameter should be about 4.8 m. This will result in a velocity of 18.5 m/s in the duct, and this velocity should also apply to the feeder ducts from Lingan Fan and Phalen Fan. There is only a small difference between the flow from Lingan and that from Phalen (ie. about 3%). Therefore, a duct size of 3.4 m diameter is a reasonable compromise for the two feeder ducts. This will result in a gas velocity of 18.2 m/s from Lingan, and 18.7 m/s from Phalen.

If the alternative of two separate ducts, one from Lingan and one from Phalen collieries, were installed, the optimum diameter would be 3.4 m. The cost of two such ducts would be of the order $16 million, ie. about $3 million more than the single duct option. The additional controls and valves, etc., called for in the single combined duct will cost much less than $3 million, therefore, the single combined duct option is selected.

The total capital cost of such a system including the fan, controls, plus indirect costs will be of the order $20 million.

3.1.2 MRA System and Controls

The MRA transmission system is similar to that considered during the 1983 study. It has, however, been modified to permit combining the MRA from both Lingan Colliery and Phalen Colliery, as well as improved conduit route selection. The design must cater to the following operational requirements, as inferred from the 1983 study.

CBDC Requirements

1. In the event of a mine emergency, it must be possible to reverse the flow in the mine ventilation system (ie. at Lingan Colliery and/or Phalen Colliery).
2. The existing MRA exhaust flow rates must be maintained under CBDC control.
3. The Lingan fan must be operationally independent of the system, as must be the Phalen fan. Thus if either fan is shut down, the system controls must compensate to reduce flow to the Lingan Generating Station.

NSPC Requirements

1. The concentration of methane must be monitored with safeguards built into the system to prevent any possible explosive mixtures arriving at the generating station.
2. The boiler operation must be able to revert to normal combustion air utilization without interruption of power generation.
3. Quantities of MRA delivered must be controlled to match boiler requirements.

System Description

The interconnection between the existing fan discharge for both mines and the proposed ducts is shown in Figure 3.1, "Utilization of Mine Return Air Concept Schematic" and Figure 3.1, "Proposed Mine Fan Connection to the Duct". Under normal operating conditions the Flap D1 is held open by a controlled latch. If the demands of the power station are less than the output of the mine fan output, the excess is exhausted to atmosphere. A methane concentration sensor M1 is located in the duct and would be set to release the latch on the Flap D1 in the event of levels of methane in excess of 2%. When Flap D1 closes, it would open a reverse flap to admit air to the duct to prevent an excessive vacuum forming, and to dilute the excess methane. The dimensions of the reverse flap would be much smaller than the duct dimensions so that an over-supply of outside air when only one of the two fans is operating, will be avoided.

Flow set dampers will be included at the mine fan off-take. These will be fixed dampers which can be adjusted to suit the normal operation of the system so that most of the MRA from both mines will be sucked into the system.

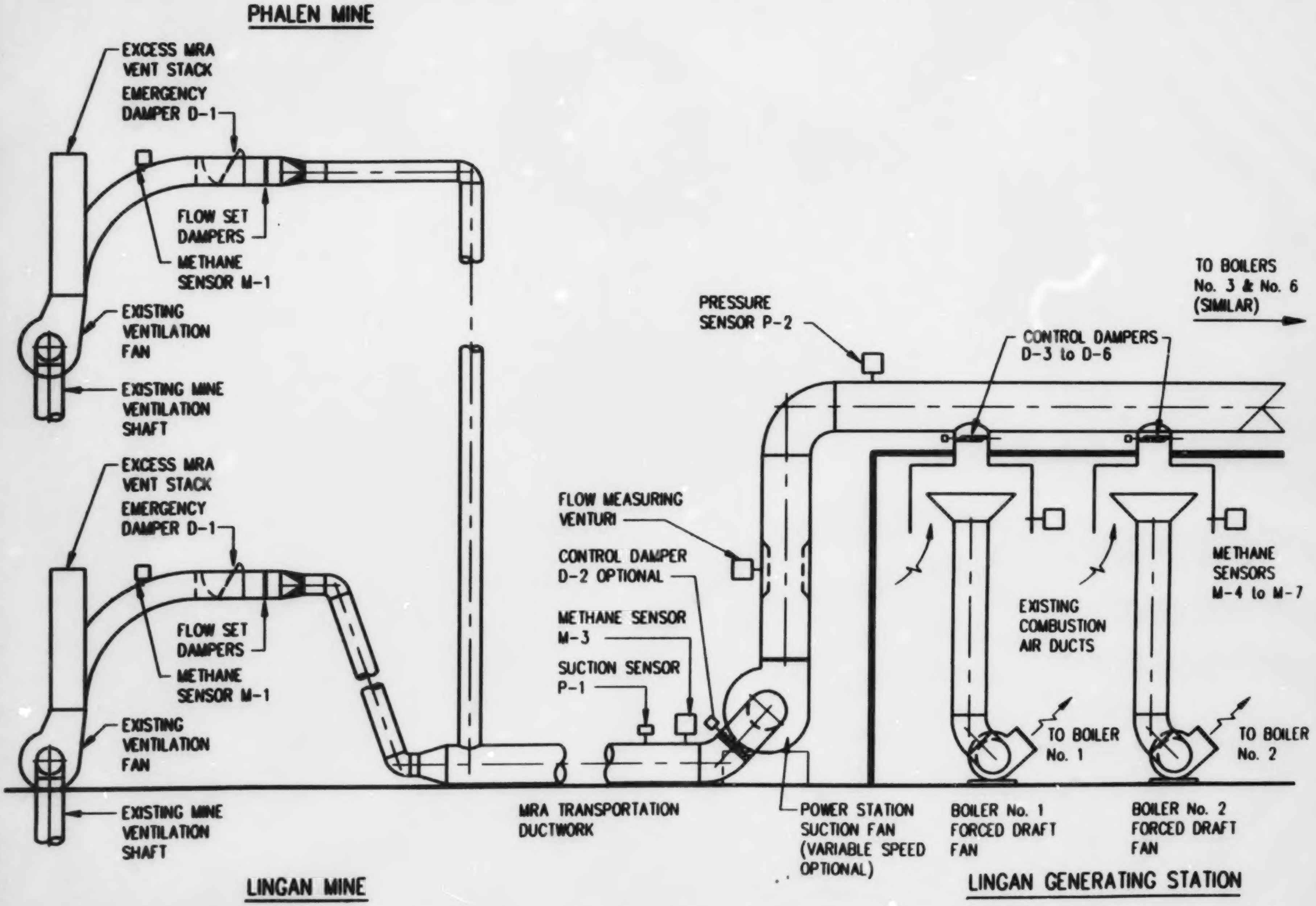

PHALEN MINE
EXCESS MRA VENT STACK
EMERGENCY DAMPER D-1
FLOW SET DAMPERS
METHANE SENSOR M-1
EXISTING VENTILATION FAN
EXISTING MINE VENTILATION SHAFT
EXCESS MRA VENT STACK
EMERGENCY DAMPER D-1
FLOW SET DAMPERS
METHANE SENSOR M-1
EXISTING VENTILATION FAN
EXISTING MINE VENTILATION SHAFT
LINGAN MINE
MRA TRANSPORTATION DUCTWORK
FLOW MEASURING VENTURI
CONTROL DAMPER D-2 OPTIONAL
METHANE SENSOR M-3
SUCTION SENSOR P-1
PRESSURE SENSOR P-2
POWER STATION SUCTION FAN (VARIABLE SPEED OPTIONAL)
CONTROL DAMPERS D-3 to D-6
TO BOILERS No. 3 & No. 6 (SIMILAR)
EXISTING COMBUSTION AIR DUCTS
METHANE SENSORS M-4 to M-7
TO BOILER No. 1
TO BOILER No. 2
BOILER No. 1 FORCED DRAFT FAN
BOILER No. 2 FORCED DRAFT FAN
LINGAN GENERATING STATION

FIGURE 3.1 UTILIZATION OF MINE RETURN AIR CONCEPT SCHEMATIC

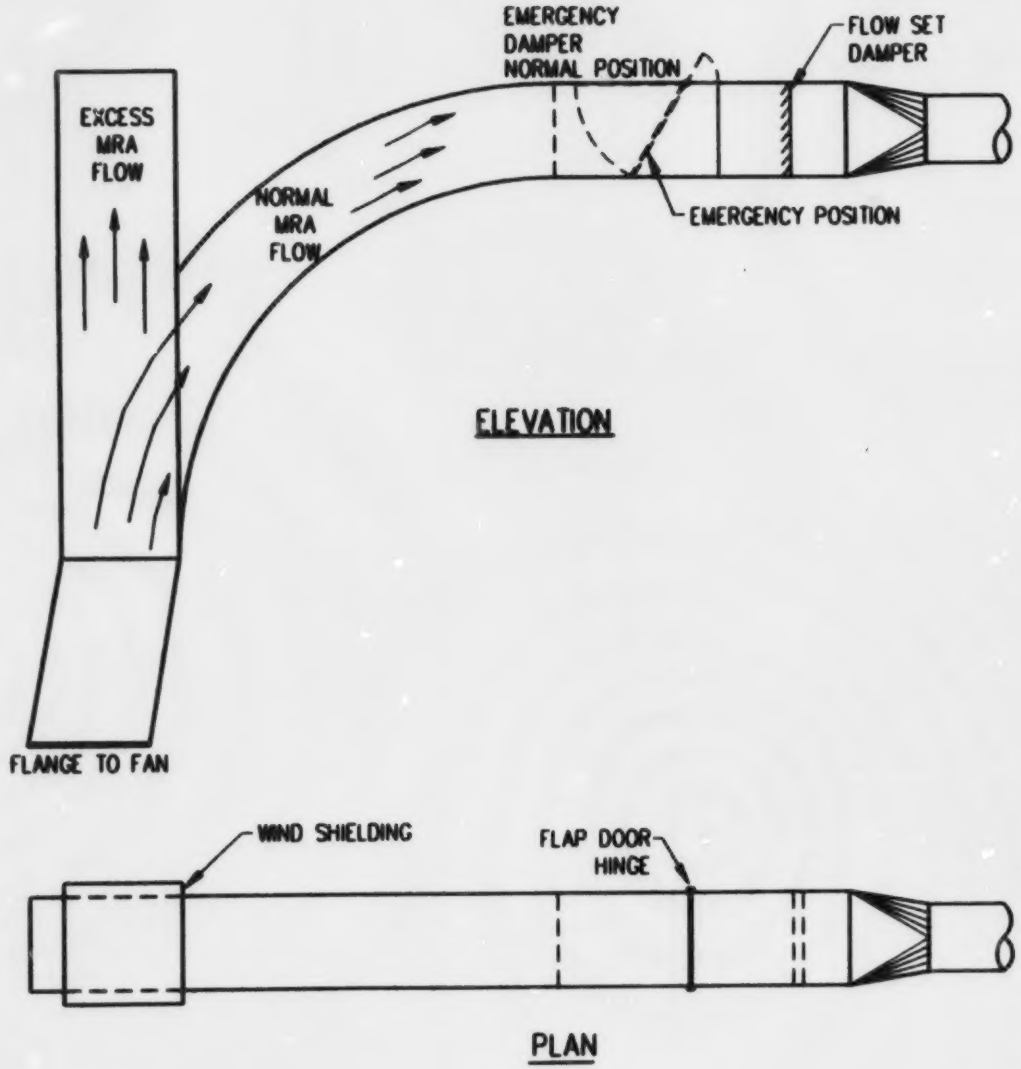


FIGURE 3.2 CONCEPTUAL DUCT CONNECTION TO MINE FAN EXHAUST

The lower flammability limit of methane at atmospheric pressure varies with temperature. The highest temperature which will be achieved by the MRA will occur after the heater at the boiler, and will be at the point of highest surface temperature in the air heater. The design data indicates a maximum air heater inlet temperature of (701°F) 372°C. Even with a dirty boiler this is unlikely to result in an air heater temperature higher than about (750°F) 399°C. It is suggested that the trip be set at 2% which corresponds to a flammability limit temperature of about (1400°F) 760°C.

Methane sensor M2 will function as a means of measuring and recording the concentration on a continuous basis. This will be used in conjunction with the flow measuring venturi to establish quantities for billing purposes. Sensor M2 will also be fitted with high and low level limit switches to initiate alarms and shut down the fan at the power station. Suction sensor P1 is arranged to stop the power station fan in the event of excessively low suction pressure. This would occur if the safety flap D1 at both mine fans were to operate. Pressure sensor P2 is arranged to maintain the pressure in the distribution manifold by varying the control damper D2. An alternative technique for controlling the pressure would be by variable speed control of the MRA fan located at the power station.

The interface between the forced draft (F.D.) fan for each boiler and the MRA system is via the control dampers D3 through D6. As the forced draft fan controls open, the corresponding dampers D3-D6 would open to admit more MRA. The range of opening of D3-D6 dampers would be such that at all times there will be a demand for boiler room air to mix with MRA. This will ensure that there will be no oversupply of MRA which could possibly collect in the boiler room. It will also ensure that the boiler room will be ventilated at all times. As a safeguard, methane sensors M3-M6 are positioned to monitor any oversupply of MRA methane, and would stop the power station fan in the event of an alarm situation.

3.1.3 Benefits/Costs MRA - 0.4%

The objective of this part of the report is to identify the financial characteristics of the project. The known environmental benefits such as reducing the discharge of methane to the atmosphere and reducing SO_2/NO_X emissions will be assessed in Section 3.1.4.

The coal burned at Lingan Generating Station is a blend of coal, mostly from Point Aconi - Prince Mine mixed with some washed coal from Victoria Junction. The objective of the blend is to maintain a monthly average sulphur content of 3.5%. The introduction of MRA would be used to displace some of the Victoria Junction coal which is more expensive and which can be marketed elsewhere.

The 1983 study assumed that the coal burned at Lingan Generating Station had different characteristics from Victoria Junction washed coal. The two sets of data for coal are shown below.

		Assumed Coal Characteristics	
	Units	1983 (study)	Coal - V.J.
Heating Value	Btu/lb.	12000	13700
Sulphur Content	%	2.44	2.00
Cost	$/tonne	45.00	70.00

Therefore in updating the results of the 1983 study, adjustments have to be made not only for an increase in MRA flow from 212 m^3/s (1983) to 335 m^3/s (1990), but also for the change in coal characteristics. The MRA system utilization is assumed at 8000 hours/year to allow for some wastage/loss of MRA.

	Benefits	Units	1983 Data	1990 Data
1.	Coal fuel displaced by MRA combustion	tonnes/yr.	26,595	36,581
2.	Ventilation heating avoided coal equivalent	tonnes/yr.	5,164	7,238

3. Reduced coal and ash handling electricity	MWh/yr	258	362
4. Reduced operating and maintenance	$/yr	18,500	22,700
Costs			
1. Power to convey MRA	MWh/yr	6,400	10,264
2. Increased power for FD & ID fans	MWh/yr.	104	106
3. Coal for preheating MRA	tonnes/yr.	3,677	5,165
4. New equipment - O & M	$/yr.	135,000	204,000
Net coal saving	tonnes/yr.	28,064	38,654
Net power consumption	MWh/yr.	6,246	10,068
Net operating and maintenance costs	$/yr.	116,000	181,300

Coal costs about $2.70 per million Btu as delivered, and the average value for electricity used at the Generating Station is $0.05.3/kWh [Ref. 7]. Therefore the potential savings can be valued at:

Coal	38,654 x 2,204 x 13,700 x 2.7 ÷ 1 million	= $ 3.15 million
Power/Energy	10,068 x 10^3 x 0.053	= [$ 533,604]
O&M Costs		= [$ 181,300]

Costs

Based on estimates performed in 1983 escalated to 1990 by using Statistics Canada ratio 1.4.

Direct Costs:	$
Duct - Complete	13.0 million
Fan, Instrumentation and Controls	0.6 million
	13.6 million

Indirect Costs:

Engineering, Procurement, Construction Management (17%)	2.3 million
Owners costs, Interest During Construction, Insurance, Customs Tariffs, Duties, Taxes, etc. (35%)	4.8 million
	7.1 million
GRAND TOTAL	**20.7 million**

Present Value Analysis

Assume:

Capital in $ for January 1, 1990
In service date January 1, 1992
In service life 20 years (ie. retired December 31, 2011)
Cost of capital 10.25%
Inflation 5%

Capital $20.7 million disbursed 50% 1990 and 50% 1991, operations and maintenance $714,900/year, expressed in 1990 dollars, starting January 1, 1992 until December 31, 2011.

Revenues from coal avoided at $2.70/million Btu as at 1990, starting January 1992 until December 31, 2011. 1990 value $3.15 million/year.

Present Values:

Investment	$20.7 million
O & M	$ 8.08 million
Total Life Cycle Cost	$28.78 million
Benefit (coal)	$35.61 million
Net Benefit	$ 6.83 million

3.1.4 Environmental Benefits of Using MRA

There are three principal benefits to the environment which can be derived from using MRA in the proposed project.

- Reduction of SO_2 emissions
- Reduction of NO_X emissions
- Reduction of methane emissions

The substitution of 38,654 tonnes of coal which contains 2.0% sulphur will result in a reduction of about 1,646 tonnes of sulphur dioxide emissions. The Province of Nova Scotia has committed to reduce $S0_2$ emissions by 15,000 tonnes/year by 1994. Therefore 1,546 tonnes is not insignificant.

In January 1990, NSPC produced an internal level III study to develop an $S0_2$ Reduction Program. Based on this report, NSPC values the reduction in SO_2 emissions at a life-cycle cost of $400/tonne (i.e. over the 20 year life of the plant) [Ref. 4]. Thus the net present value of SO_2 reduction is 1,546 x 400 x 20 = $12.37 million.

When MRA is used as combustion air the NO_X levels reduce approximately in proportion to the reduction in the amount of coal used. Methane in MRA represents about 3% of the total annual fuel, so the NO_X emissions will reduce by about 3%.

The most recent test data available indicates NO_X emissions of 400-450 ppm vd at maximum continuous rating (MCR) of the Lingan units. From rudimentary calculations, this equates to about 12,000 tonnes/year. The reduction will therefore be 360 tonnes/year. NSPC has not developed a notional value for NO_X reduction and none is proposed here because it really does not affect the validity of the project.

The emission of methane is not listed as a contaminant which is likely to be regulated in the near future. However it is estimated to contribute to the greenhouse effect at a rate of 30 times the effect of an equivalent volume of carbon dioxide. The annual volume of methane contained in MRA is equivalent to the carbon dioxide emitted from a thermal power plant of about 300 MW operating year-round.

4.0 CONCLUSIONS - UTILIZATION OF MRA

The supply of MRA from Phalen mine is regarded as secure, and likely to increase. The supply from Lingan is contingent upon continued federal government financing and the performance of the operators of the mine. If both mines continue operating, the proposed large duct with feeder ducts from each mine promises to be an attractive project. Real savings valued at a net present value of $6.83 million can be realized.

The project also provides for reducing emissions to the atmosphere which can be valued at least $12.37 million for reducing SO_2 emissions.

If Lingan mine were not operating, the project is still like to be a better than break-even proposition, but will depend on projections for increased MRA flows from Phalen mine. An alternative idea would be to continue operating the Lingan ventilation fan at some reduced flow. Methane will continue to dissipate from the old workings for a number of years.

5.0 SUPPLY AND USE OF MINE DRAINAGE METHANE

This part of the interim report deals with the potential supply and use of Mine Drainage Methane (MDM) in concentrations 45% - 60% methane in air.

The question to be resolved in this part of the study, is whether the reduction in NO_X which can potentially be realized by co-combusting methane with coal, is worth the extra expense of MDM processing and transmission. Published experimental data reported in JAPCA - October 1989 [Ref. 8] shows that when fuel (methane) is injected above the main heat release zone, hydrocarbon radicals from the combustion process react with nitric oxide to form nitrogen.

In order to obtain data specific to the coal used at Lingan, and the gas available from Lingan Mine, CANMET Laboratories were commissioned to do tests. These were undertaken June 1990, and they showed that some reduction in NO_X is achieved. The results are discussed in detail in Section 5.3 of this report.

The alternative use of MDM would be to add it to the MRA system described in the previous pages of this Report. Such a system would be very cheap to install as an addition to the proposed MRA supply system. Thus the evaluation of the MDM utilization system comes down to the reduction of NO_X achieved by reburning versus the increased capital, operating and maintenance costs which will be incurred. It must be noted that NO_X reduction will be achieved by burning the methane in place of coal. This amounts to displacing about 32,000 tonnes/year of coal by using MDM.

5.1 MINE DRAINAGE METHANE - QUANTITIES AND QUALITIES

As for Section 2.1 the following text is based on a letter 1990-04-25 from CBDC to the Study Technical Steering Committee [Ref. 3].

Long term mining is planned for both Lingan and Phalen, and present mining plans are such that the methane flows as outlined in the following paragraphs will be sustained for at least 10 years. The word "methane" as used here means aliphatic hydrocarbons made up of 95% methane and diminishing amounts of higher weight gases.

Currently, contained methane flow from the gas extraction plant (MDM) is in the range of 0.5 to 0.6 cubic meters per second (m^3/s) originating from the drainage system plus 0.15 m^3/s from the sealed longwalls. At this time CBDC recommends a long term supply from the Lingan gas extraction system be allowed for at 0.5 m^3/s of contained methane. This methane is diluted with entrained air. The total gas mixture flow is therefore between 0.9 and 1.0 m^3/s. Similar flows and qualities are assumed for the future Phalen MDM system.

The methane content of the MDM is now about 50%. With more attention to control of flow and quality from individual drainage holes this can easily be raised to 55% and with some additional expenditure in time and equipment a level of 60% is attainable. To improve quality substantially beyond 60%, if possible at all, would be very costly. The quality of the gas is expected to be easier to maintain as conversion to retreat mining is completed.

It is assumed that at the time this project would be implemented, CBDC will have installed a similar MDM system at Phalen Mine which will boost the total to 1 m^3/s of methane in a mixture with an almost equal amount of air. This quantity of gas as a fuel would displace about 32,000 tonnes per year of Victoria Junction washed coal as fed to Lingan Power Plant.

5.2 POWER PLANT INTERFACE

The MDM supply is sufficient for one boiler only. It is unreasonable to expect much greater than a capacity factor of 85% for one boiler, so it would be necessary to interconnect the MDM supply with the MRA at the power plant. Thus, at times when MDM is not required for NO_X control, it can be dumped into the MRA and used to displace coal on the boilers by using MRA as combustion air.

Details of how and where the MDM will be introduced to the boiler have not yet been developed pending a decision to proceed with this over-all approach.

5.3 MDM COMBUSTION TEST RESULTS

Canmet presented preliminary test results at a Project Review meeting July 6, 1990. They are reproduced here as Table 5-1. It can be seen that MDM injection would result in a reduction of NO_X. If the projected MDM quantity from Lingan plus Phalen is realized, then it would represent 8% of the fuel for one boiler at full load. Under these conditions, the likely NO_X reduction would be of the order 15%. This percentage applies to a burner which produced 800 ppm. NO_X whereas it is known that the burners at Lingan produce about 400 ppm NO_X, so the 15% would result in about 60 ppm. reduction. Further to this, NSPC has stated that, by means of relatively inexpensive modification and optimization, figures of 280 ppm are predicted for Lingan boilers. In which case the MDM would result in only an improvement of about 45 ppm. reduction.

It must be remembered that the total MDM supply displace about 8% of the coal to one boiler. So that 8% NO_x reduction can be attributed to fuel displacement. Therefore, the net benefits of this technique as opposed to blending MDM with MRA as combustion air, are an improvement from 8% to 15%. This could be as little as about 25 ppm.

The Canmet test results show that by using natural gas (NG), the NO_x reduction is better than when using simulated MDM at ratios of 77/23 and 50/50 air/NG.

TABLE 5-1

CANMET MRA & REBURN TESTING: PRELIMINARY SUMMARY

TEST	MRA COMB. AIR NG CONC.	MDM - REBURN		NOX REDUCTION[2]
		RATIO AIR/NG	FRACTION OF LOAD[1]	
Baseline	---	---	---	---
MRA only	0.5%	---	---	~5%
MRA only	1.0%	---	---	~5%
NG Reburn	---	0/100	6.5%	~15%
NG Reburn	---	0/100	10%	~28%
NG Reburn	---	0/100	4%	~5%
Reduced Load	---	0/100	10%	~28%
MDM Reburn	---	77/23	10%	~20%
MDM Reburn	---	77/23	4%	~5%
MDM Reburn	---	50/50	10%	~20%
MDM Reburn	---	50/50	4%	~5%
ALL	0.5%	50/50	10%	~20%
ALL	0.5%	50/50	4%	~5%

NOTES:

1. Fraction of load: the test burner is rated at 1.6 million Btu/hour.
2. NO_x reduction: the test burner at baseline conditions produces 800 ppm. NO_x.

Nomenclature:		
MRA	-	Mine Return Air
MDM	-	Mine Drainage Method
NG	-	Natural Gas

6.0 MDM TREATMENT AND DELIVERY SYSTEMS

Two delivery systems are considered. In the first, one, the gas would be taken from the existing MDM extraction plant discharge system, compressed, cleaned and piped to the selected boiler at the plant, this is discussed in Section 6.1. The alternative is to use a system of concentrating the methane at the mine prior to transmission to the power plant. This is discussed in Section 6.2

6.1 MDM TREATMENT AND DELIVERY - SIMPLE COMPRESSOR SYSTEM

The 1988 study [Ref. 2] undertaken for CBDC by Fenco Shawinigan into the "Potential for Cogeneration Using MDM," included the conceptual design and cost estimate of a system to take MDM and compress it, treat it and deliver it to a proposed reciprocating engine - power plant. The system is very similar to what would be required for delivery of MDM to Lingan Generating Station.

Gas extracted from the mine will be conveyed by means of an above-ground pipeline to a compressor building located outside of the mine head. The gas will be dried in order to remove significant amounts of condensate prior to entry into the compressors by means of a cyclone air dryer. It will then be distributed to each compressor via a valve and piping system. Inlet gas conditions are expected to be approximately 60°F, 15-18 psia (0.3 to 3.3 psig) reaching a potential flow rate of up to 4.4×10^6 scfd when gas purity falls to 45% methane. The chemical energy component of the gas will normally be 50 - 55% methane (by volume). Delivery pressure would be 75 psia (60 psig). This would be adequate for flow control at the burners.

Two types of compressor were considered for this application: reciprocating piston type, and rotary sliding valve type. The latter was selected. The compressor size was selected at 50% duty so that any two of three in service could meet full requirements.

Gas will be discharged from the compressors at approximately 315°F, 75 psia (60.3 psig). After-cooling will reduce the temperature to approximately 120°F.

Water and heavy gases such as propane and butane, etc., in the liquid state will exist as a result of the compression and cooling. These must be removed because accumulated amounts of this liquid will accelerate the corrosion of the gas delivery pipeline. Gas clean-up will be accomplished with a filter system located in the gas line downstream from the after-cooler.

The gas will be saturated with vapour after passing through the after-cooler and liquid filter. Therefore, any cooling taking place in the gas delivery pipeline will resulting in condensation in the pipeline. To avoid this, immediately after the liquid filter, the gas will pass through a heat exchanger to increase its temperature by 305°F. Heat will be provided by hot compressed gas emanating from the compressor discharge. This increase in temperature will be sufficient to compensate for any gas cooling during its transit between the compressor plant and the power plant. The total gas system is shown in Figure 6.1 and 6.2.

An airtight electrical equipment building will be located separately from the compressor building. This will minimize costs by avoiding requirements for explosion-proof equipment. The three compressors will be fed from a line-up of medium voltage motor starters housed in the building.

A pipeline of about 200 mm diameter complete with insulation and protective coatings will convey the gas to the Lingan Generating Station.

LEGEND

1. Ro-Flo Compressor
2. Drive Motor
3. Coupling
4. Lubricator
5. Intake Filter
6. Differential Pressure Gauge
7. Bedplate
8. Automatic Drainer
9. Pressure Gauge
10. High Temperature Limit Switch
11. Temperature Gauge
12. Check Valve
13. Aftercooler
14. Moisture Separator
15. Pressure Relief Valve
16. Bypass Flow Regulator
17. Water Flow Regulator
18. Water Solenoid Valve
19. Water Strainer

)(Denotes Open Drain

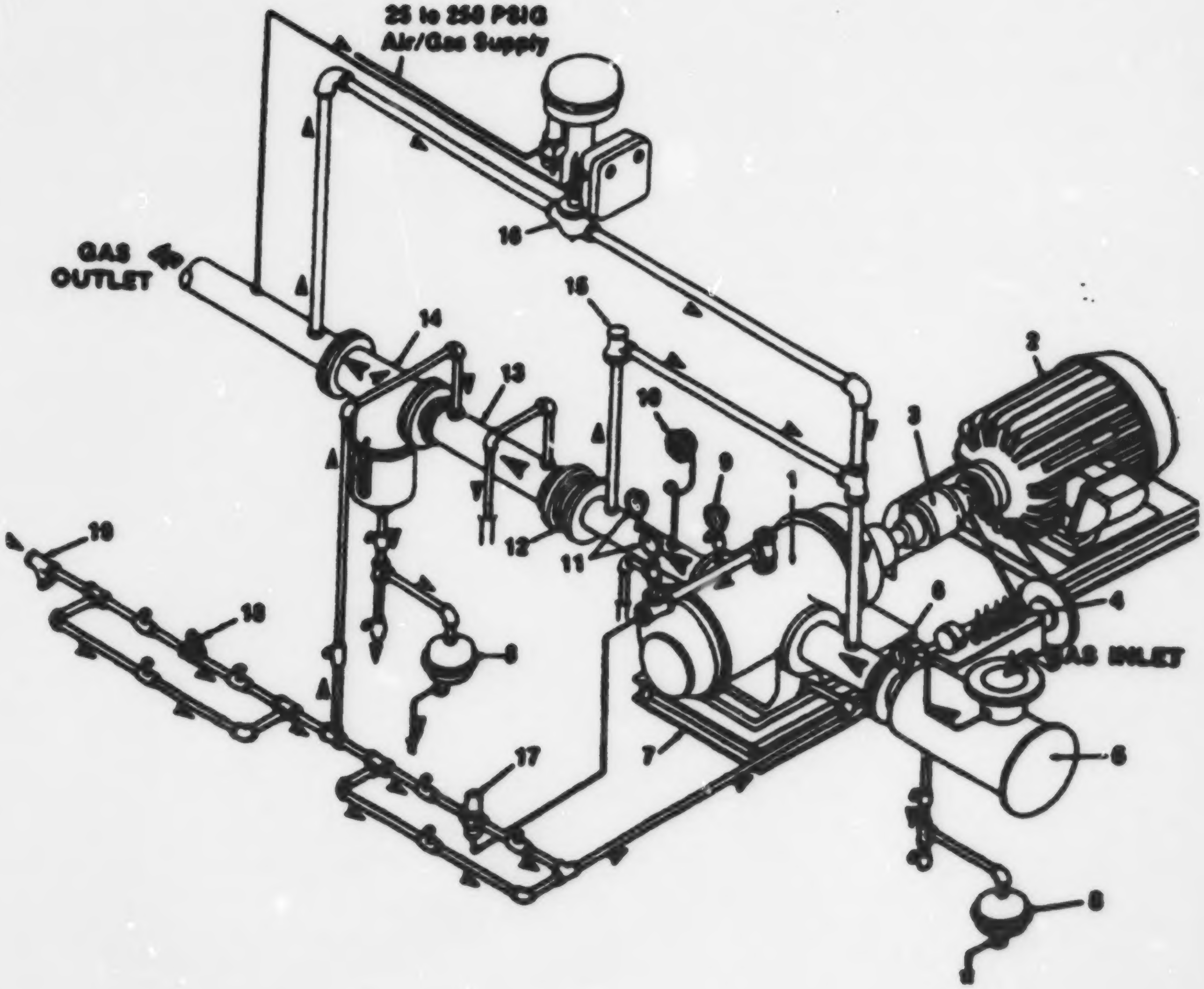


FIGURE 6.1 MDM COMPRESSOR PIPING ARRANGEMENT

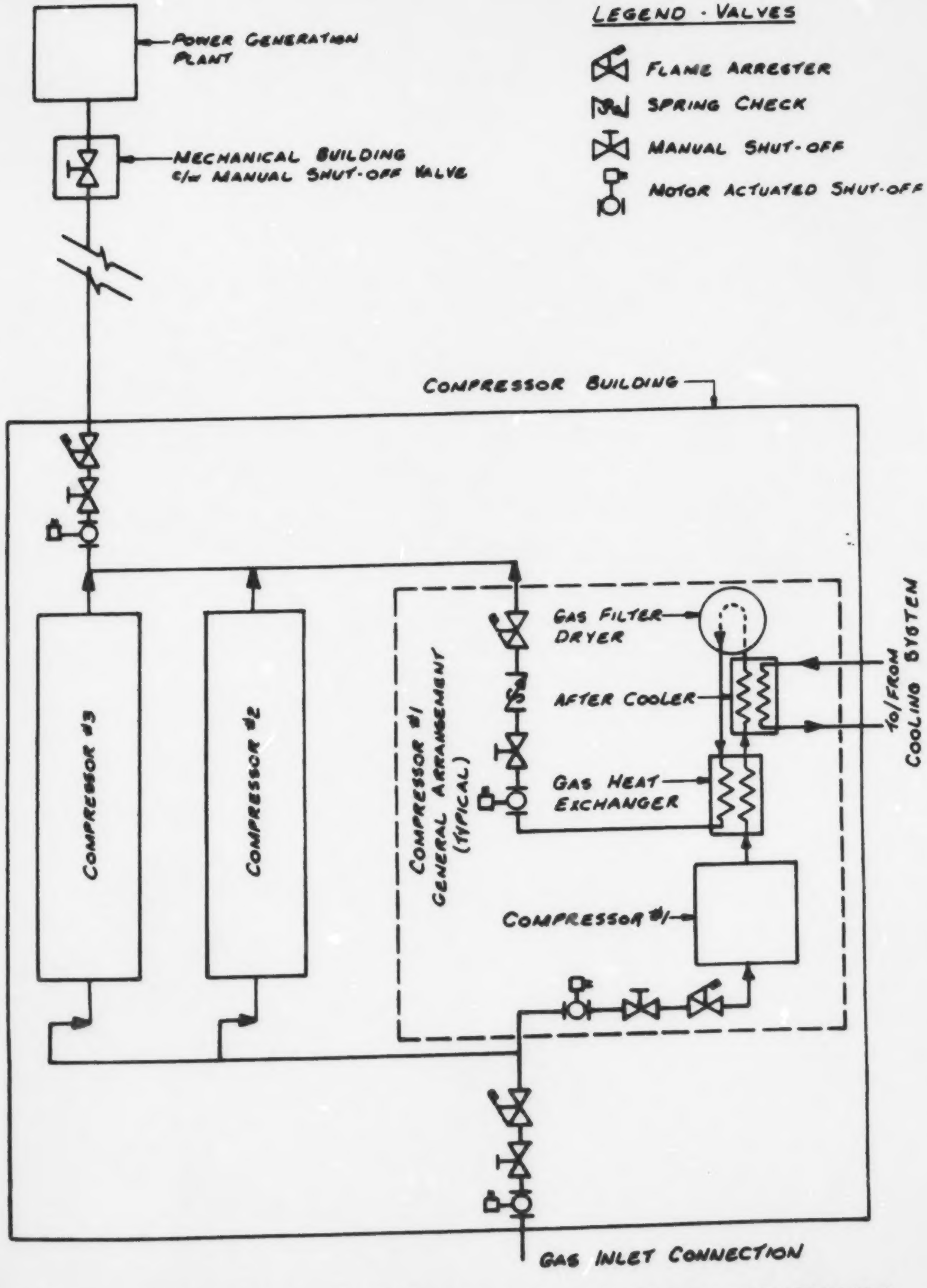


FIGURE 6.2 MDM GAS FLOW & VALVE SYSTEM SCHEMATIC

6.1.1 Gas Supply System Control

There are three elements in the gas supply system which affect the quantity of gas to be delivered to the power plant:

- The existing gas extraction plant rate of delivery.
- The proposed compressors rate of delivery.
- The gas quantity required by the boiler.

A schematic of the control system is shown as Figure 6.3.

The principal concern is that the existing gas extraction plant must be able to continue operating regardless of the status of the new system. The existing vacuum pumps are capable of discharging against a back pressure of 5 psig; so the existing discharge vent will be set to relieve at this pressure. A control system will be installed to control the back-pressure on the vacuum pumps between 1.0 and 5.0 psig. In the event of a pressure excursion outside of these limits, alarms would be activated, and the compressors shut down. The discharge pressure would be controlled by a system of recirculation of part of the gas. Abnormally high discharge pressure such as would occur when zero gas is required, will result in a compressor shut down.

6.1.2 Compressor Building

The three compressors require a structure 33 feet long by 26 feet wide by 14 feet high. A separate building will house the electrical switchgear and controls.

The compressors and associated after-coolers will require a closed circuit evaporative cooler located outside the compressor building. This will cool 300 U.S. gallons per minute over a range of 15°F at a temperature approach of 42°F.

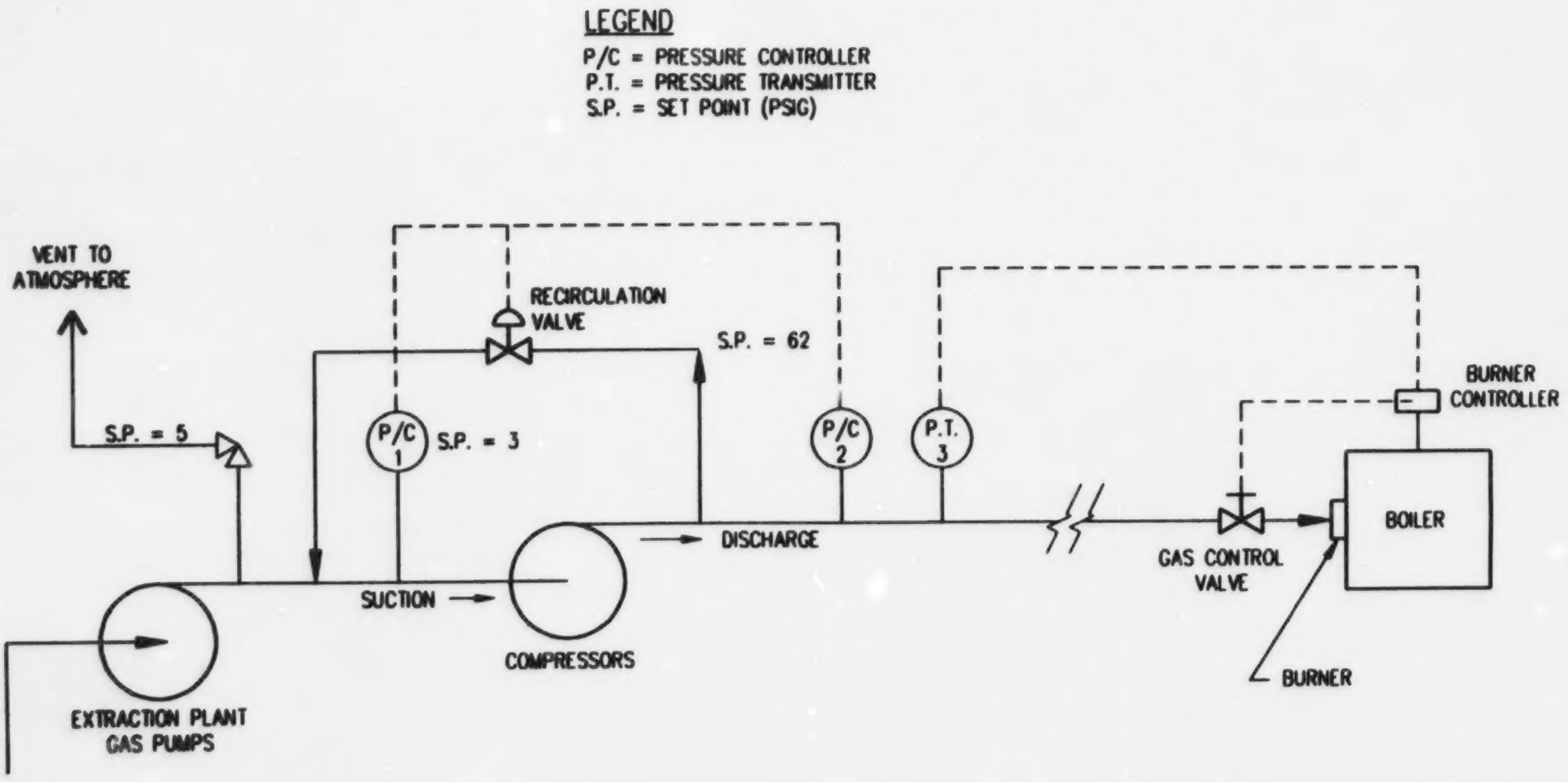


FIGURE 6.3 MDM CONTROL SYSTEM SCHEMATIC

Compressed gas exiting the compressor building will be immediately injected with gas odorizer. This will allow human detection of gas escaping from the distribution line. Sufficient odorizer storage will exist to allow for replenishment on a monthly basis.

6.1.3 NOx Reduction Due to MDM Reburning

The benefits of using MDM as a reburn fuel must be considered in comparison to the alternative use of MDM. That is to say, in comparison with simply blending it with MRA at Lingan mine so that it enriches the methane concentration and contributes to coal fuel displacement in the boilers.

MDM in the quantities/qualities stated, would displace about 8% of the coal/fuel for one boiler. Thus a reduction of about 8% NO_x is achieved by fuel displacement. The balance is attributable to the effect of the hydrocarbon radicals in the combustion process, and this contributes a further 7%.

The annual NO_x emission at maximum continuous rating, equate to about 3,000 tonnes/year per boiler. Thus a 7% reduction on one boiler equates to about 210 tonnes/year.

6.2 MDM GAS CONCENTRATION SYSTEM

In view of the improvements in NO_x reduction which can be obtained if concentrated methane is used as a reburn fuel, instead of MDM, the possibility of concentrating the gas was investigated. After some preliminary review of various potential technologies, Pressure Swing Adsorption was seen as the best candidate technology.

6.2.1 Pressure Swing Adsorption Process

The pressure swing adsorption process is based on the principle that an adsorbent can retain more impurities as the pressure increases. Thus, when a mixture of gases are pressurized in a container of adsorbent, the adsorber can be selected to facilitate separation of certain molecules. As the pressure swings from a high level to a lower one, adsorbed gases are desorbed and released to a discharge system.

Thus, in the case of methane, an adsorbent is selected which effectively adsorbs this gas in preference to oxygen and nitrogen. By designing a unit with a multiplicity of vessels the system can be operated on a continuous supply basis.

UOP Canada Inc. supplied information on a typical hydrogen purification system. It is understood from discussions with UOP marketing manager Heinz Ecker, that the methane purification would operate with an adsorber which removes methane. The system operation is described below and is shown in Figure 6.4 - Pressure Swing Adsorption Process.

i) Adsorption: Feed gas ± 50% methane in air, is introduced into an adsorber at 75 psig, 100°F for a flow of 4.0 million scf/day, a 500 h.p. compressor would be required. The methane is adsorbed, and air is available for withdrawal as a vent, it will contain 7.8% methane and can be released to the MRA system.

ii) Depressurization: The adsorber is partially depressurized by releasing air, all of which is used to purge and repressurize another vessel (Step 4).

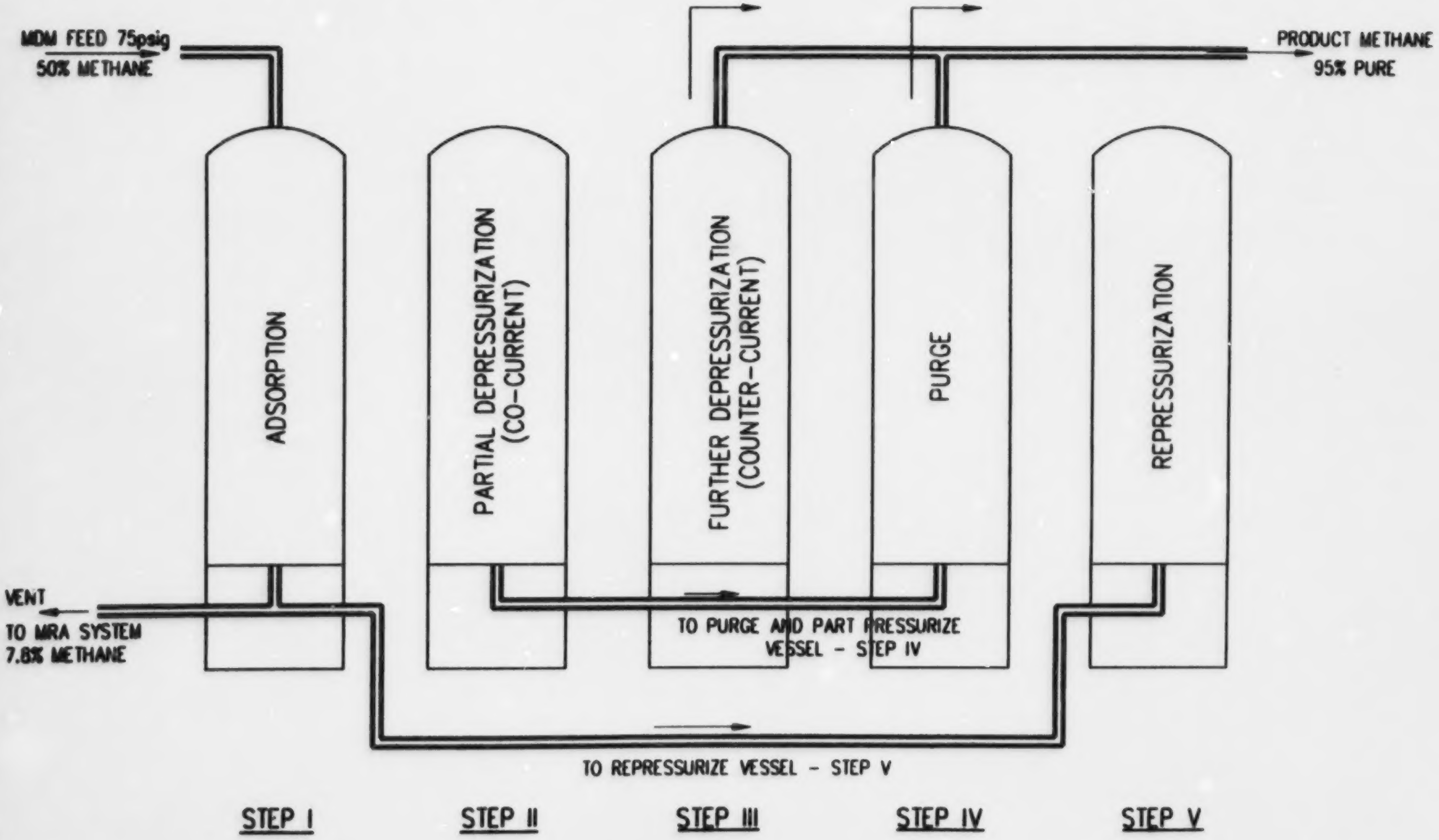


FIGURE 6.4 MDM PRESSURE SWING ADSORPTION PROCESS

iii) Counter-current depressurization: The adsorber is further depressurized to its lowest pressure level. The adsorbent is partially regenerated and some methane is discharged to the supply system.

iv) Purge: Air from Step i) is used to purge the remaining methane and complete the regeneration of the adsorbent.

v) Repressurization: The adsorber is repressurized with air from Step i). When it is fully pressurized, it is ready to receive feed as in Step i). The cycle can now be repeated.

	Feed	Vent	Product CH4
Flow, MM SCFD	4.0	2.0	2.0
Pressure, PSIG	75	65	75
Temp. DEG F	100	110	100
COMPOSITION, %			
N_2	40	73.8	4
O_2	10	18.4	1
CH_4	50	7.8	95

DESIGN METHANE RECOVERY = 90%

ESTIMATED PSA COST	$1.6 Million
ESTIMATED FEED GAS COMPRESSION	500 HP
ESTIMATED PRODUCT GAS COMPRESSION	390 HP

6.2.2 NOx Reduction Due to Concentrated MDM Reburning

The evaluation of concentrated MDM as a reburn fuel is similar to that undertaken in Section 6.1.3 for MDM (as received). The improved reduction in NO_X emissions is an increase from 15% to 20% in total reduction. When this is reduced by 8% to 12% to account for NO_X reduction as a result of simple fuel substitution, the benefit equates to 360 tonnes/year. This figure must be further modified because there will be a 10% loss of methane in the Pressure Swing Adsorption process. Thus the net reduction will be 340 tonnes/year.

6.3 MINE DRAINAGE METHANE - COLLECTION AND SUPPLY - COST ESTIMATES

A) Simple Gas Clean-up and Compressor System

Cost Estimate (1.13 x June 1988 Costs)		$
Division 1	Site Development	38,462
Division 2	Building and Structures	46,000
Division 3	Gas Compressor/Supply Pipe ($70/metre)	1,255,651
Division 4	Electrical System	259,253
(Division 5	Allowance for interconnection to power plant	1,000,000)
		2,599,366
Add 55% for indirects		1,429,651
	TOTAL	$4,029,017

Operations: 450 kW x 8760 x 0.053 = $209,000/yr.
Maintenance: at 4% of direct costs = $104,000/yr.
Total O & M: $313,000/yr

B) Gas Benefication System

Cost Estimate: 1.51 x Simple Clean-up *

Division 1	Site Development	58,000
Division 2	Buildings and Structures	327,000
Division 3	Gas: Process Plant	1,600,000
	Pipeline at $70/metre	210,000
Division 4	Electrical System	393,000
(Division 5	Allowance for Interconnection to Power Plant	1,000,000)
		3,588,000

Add 55% for Indirects	1,973,000
TOTAL	$5,561,000

* The factor 1.51 is derived from the ratio of power required by the Benefication System, to the power required by the Simple Compressor System. This ratio is raised to the power 0.6 which is a suitable index for determination of costs.

Operations: 800 kW x 8760 x 0.053/c/kWh = $371,400/yr.
Maintenance: at 4% of direct costs = $144,000.
Total O & M: $515,000.

Present Value Analysis

Assume:
Capital in $ for January, 1990
In service date January 1, 1992
In service life 20 years (i.e. December 31, 2011)
Cost of capital 10¼%
Inflation 5%

A) Simple MDM Gas Clean-up and Compressor System

Capital $4,029,017 dispersed 50% 1990 and 50% 1991. Operations and maintenance $313,000/yr., starting January 1, 1992 until December 31, 2011.

Present Values:

Investment	$4.029 million
O & M	$3.538 million
	$7.587 million

Over the 20 year life of the project the NO_x emission will be reduced by 210 x 20 = 4200 tonnes at a cost (1990) of 7.567 million. That is to say $1801/tonne.

B) Concentrated MDM PSA and Delivery System (beneficiation)

Capital $5,561,000 dispersed 50% 1990 and 50% 1991
Operation and Maintenance $515,0900/yr., starting January 1 1992 until December 31, 2011.

Present Values:

Investment:	$ 5.56 million
O & M:	$ 5.82 million
	$11.38 million

Over the 20 year life of the project the NO_X emissions will be reduced by 324 x 20 = 6,480 tonnes at a cost (1990) of $11.38 million. That is to say $1,756/tonne.

6.3.1 Benefits / Costs of Using MDM

The objective of this part of the report is to identify the financial characteristics of utilizing MDM independently from the MRA system discussed in Section 3.0. The analysis is similar in that financial benefits are derived from displacing Victoria Junction washed coal. Environmental benefits are quantified in a similar fashion to the approach discussed in Section 3.1.4 for using MRA.

Costs/Benefits Analysis of Using MDM as a Reburn Fuel

	Benefits	Units	Simple System	Benefic. System
1.	Coal fuel displaced by MDM combustion	tonnes/yr.	32,000	32,000
2.	Reduced coal and ash handling electricity	MWh/yr.	317	317
3.	Reduced operating and maintenance	$/yr.	19,857	19,857

Benefits	**Units**	**Simple System**	**Benefic. System**
1. Power to convey MDM	MWh/yr.	3,942	7,008
2. New equipment - O & M	$/yr.	313,000	144,000
Net coal saving	tonnes/ur.	32,000	32,000
Net power consumption	MWh/yr.	3,625	6,691
Net operating and maintenance costs	$/yr.	293,143	498,623

MDM - Beneficiation System

Coal 32,000 x 2,204 x 13,700 x 2.7 ÷ 1 million = $2.61 million

Power/Energy 6,691 x 10^3 x 0.053 = [$354,623]

O & M Costs = [$498,623]

Present Value Analyses

Assume:

Capital in $ for January 1, 1990
In services date January 1, 1992
In service life 20 years (i.e. retired December 31, 2011)
Cost of capital 10.25%
Inflation 5%

Capital disbursed 50% 1990 and 50% 1991, operations and maintenance, expressed in 1990 dollars, starting January 1, 1992 until December 31, 2011.

Revenues from coal avoided at $2.70/million Btu as at 1990, starting January 1992 until December 31, 2011. 1990 value 2.61 million/year.

Present Values:

	MDM - Simple	MDM - Benefic.
Investment	$ 4.02 million	$ 5.561 million
O & M	$ 5.48 million	$ 9.643 million
Total Life Cycle Cost	$ 9.50 million	$15.204 million
Benefit (coal)	$29.51 million	$29.51 million
Net Benefit	$20.01 million	$14.306 million

6.3.2 Environmental Benefits of Using MDM

There are three principal benefits to the environment which can be derived from using MDM in the proposed project.

- Reduction of SO_2 emissions
- Reduction of NO_X emissions
- Reduction of methane emissions

The subsitution of 32,000 tonnes of coal which contains 2% sulphur will result in a reduction of about 1,280 tonnes of sulphur dioxide emissions.

NSPC does not have readily available figures for the value of reduction in NO_X emissions. However, the projected life-cycle costs of using MDM (as a incremental cost over blending with MRA) are $1,801/tonne for the simple system and $1,756/tonne for the beneficiation system.

As discussed in Section 3.1.4, NSPC values the reduction in SO_2 emissions at a life-cycle cost of $400/tonne (i.e. over the 20 year life of the plant) [Ref. 4]. Thus the present value of SO_2 reduction is 1,280 x 400 x 20 = 10.24 million.

6.4 CONCLUSIONS - UTILIZATION OF MDM

The use of MDM as a reburn fuel can reduce NO_X emissions. If the MRA system will not be built, then the financial benefits of a delivery system are attractive. On the other hand if an MRA conveying system will be built, nearly all of the benefits achievable by conveying MDM on its own can be realized by blending in MDM with MRA at Lingan Mine, and this can be done at a fraction of the lifecycle cost of the MDM conveying system. The only advantage of conveying MDM on its own, is the potential for NO_x reduction. The cost/tonne of NO_x avoided is $1,801 for the simple delivery of MDM, and $1,756 if a methane benefication system is used. These "micromental" costs over the alternative MRA/MDM blending system discussed in Section 8.0 are high. Other NO_x abatement systems can achieve the same reduction cheaper.

7.0 MDM/MRA INTEGRATED SYSTEM

The benefits of using MRA can be nearly doubled at little extra cost if MDM is blended in. The only only benefits not realized by this approach are marginal improvements in NO_x reduction. The incremental life cycle costs of incremental NO_X abatement by using MDM or concentrated methane in Lingan boilers are high. Therefore the integration of MDM and MRA at Lingan Mine, must be investigated. This will lead to facilitating a decision on which method to adopt.

The Nash vacuum pumps at Lingan Mine which discharge MDM to atmosphere right now (1990), can operate against a back pressure up to 5 psig. The MRA ventilation fan is within 100 m of the facility, so all that is required is a short pipeline at about 300 mm diameter to feed MDM to the proposed 3.4 m diameter MRA duct.

At the duct, the MDM must be diffused into the MRA in such a way that there is no possibility of generating an explosive or combustible mix of MDM/MRA. The flammability limits for methane in air are 5.3 vol. % - 14.0 vol. %. The flame propagation rate is maximum 0.4 m/s (Ref: Marks Engineering Handbook 7-34). MRA from Lingan Mine is rated at 165 m^3/s, while MDM (50% methane) is rated at 2 m^3/s. The duct velocity is designed for 18.2 m/s. The MDM diffuser velocity should, therefore, be in excess of that by a margin of say 10 m/s, ie. 28 m/s. Thus, if a reduction in demand for MRA reduces its flow, the relative velocity will increase and prevent the possibility of achieving a situation where combustion could be sustained.

Safeguards would be necessary at the point of admission of MDM into the MRA system. The following is a suggested (but not necessarily exhaustive) list.

- MRA flow detection/trip device.

  This would cause an MDM shut-off valve to operate when a low MRA flow is sensed. This would protect against discharging MDM into the MRA unit until the MRA system had sufficient flow to ensure adequate dilution.

- Methane concentration detection located near the diffuser, say 2 m down-stream, and 2 m up-stream.

  These would detect and alarm/trip the MDM shut-off valve. Essentially the system is a back-up to the flow detection/trip device.

- Methane concentration detection located, say 60 m down-stream (two sensors).

  These would monitor the methane concentration of the mixed gas. The first sensor would trip the MDM shut-off valve in the event of sensing a value greater than, say, 1.5%. The second would release the emergency by-pass door and release MRA to atmosphere if the level exceeded, say, 2%. The emergency by-pass door, by design, will let fresh air in when it is released. Thus the methane concentration will reduce.

7.1 MDM/MRA INTEGRATED SYSTEM - COST ESTIMATE

The integration of the MDM system with the proposed MRA system is very much more simple than other MDM utilization options. The cost of such an interconnection is expected to be less than $0.5 million. Although this estimate may be ± 50% accurate, the error will not impact to any appreciable extent on the over all assessment of the project. This figure must be added to the costs for the MRA duct system which are detailed in Section 3.1.3 of this report.

Direct Costs

	$
Duct complete	13.0 million
Fan, Instrumentation and Controls (Duct)	0.6 million
MDM connection and controls	0.5 million
	14.1 million

Indirect Costs

Engineering, Procurement Construction Management (17%)	2.4 million
Owners costs, Interest During Construction, Insurance, Customs Tariffs etc. (35%)	4.9 million
	7.3 million
Grand Total	21.4 million

Benefits - MRA Mixed with MDM

MRA = 335 m^3/s at 0.4% methane
MDM = 0.5-0.6 m^3/s from Lingan
= 0.4-0.5 m^3/s from Phalen (future)
Total = 1m^3/s MDM (methane)

Benefits

1.	Coal saved from MRA	tonnes/yr.	36,581
2.	Coal saved from MDM based on 8000 hrs., 9508 hr./cft	tonnes/yr.	32,000
3.	Ventilation heating avoided in terms of coal saved	tonnes/yr.	7,238
4.	Reduced coal & ash handling in terms of electricity	MWh/yr.	679
5.	Reduced O & M	$/yr.	42,557

Costs

1.	Power to convey MRA & MDM	MWh/yr.	10,300
2.	Increased power - FD + ID fans	MWh/yr.	311
3.	Coal for pre-heating MRA + MDM	tonnes/yr.	5,165
4.	New equipment O & M	$	205,000

Net coal savings	tonnes/yr.	70,654
Net power consumption	MWh/yr.	9,932
Net O & M costs	$/yr.	162,443
Net sulphur dioxide avoided*	tonnes/yr.	4,946

Coal costs $2.70 per million Btu delivered, and the average value of electricity used at the Generating Station is $0.053/kWh. Therefore the potential savings can be valued at:

Coal, 70,654 x 2204 x 13,700 x 2.7 divided 1 million = $5.76 million

Power/energy 9932 x 10^3 x 0.053 = $526,396

O & M Costs = $162,443

Present Value Analysis

Assume:

Capital in $ for January, 1990
In service date January 1, 1992
In service life 20 years (i.e. retired December 31, 2011)
Cost of capital 10.25%
Inflation 5%/year

*Sulphur dioxide avoided is based on coal with a 3.5% sulphur content.

Capital $21.4 million disbursed 50% 1990 and 50% 1991. Operations and maintenance $688,843/year. (This figure is less than O & M for MRA (0.4%) because there are increased savings in coal preparation plant costs etc.) Starting January 1, 1992 until December 31, 2011.

Revenues from coal above at $2.70/million Btu as at 1990, starting January 1, 1992 until December 31, 2011 - 1990 value is $5.76 million/year.

Present Values

Investment	$21.40 million
O & M	$ 7.79 million
Total Life Cycle Cost	$29.19 million
Benefit (coal)	$65.11 million
Net Benefit	$35.92 million

8.0 MDM/MRA UTILIZATION - RECOMMENDED PROJECT

From the results of the tests by Canmet, together with the knowledge and understanding given by NSPC personnel that significantly cheaper NO_X abatement techniques are available, it is clear that the MDM/MRA integrated system is preferred.

The cost estimating techniques used in the preparation of this interim report are somewhat crude. Essentially, data developed for the previous studies in 1983 and 1988 have been updated using ratios provided by Statistics Canada. The estimation of benefits is based on current information, however, they are heavily dependent upon CBDC prediction of quantities and reliability of flows. It is understood from recorded data provided by CBDC, that the actual data used here is conservative and benefits are expected to be greater than this report suggests. This assumes that Lingan Mine will remain in operation. Even if Lingan were to close it is expected that the project will remain attractive.

From the available information, there is a very clear indication that the integrated MDM/MRA system besides being financially attractive, it also achieves most of the benefits to the environment which were projected at the outset.

- SO_2 reduced by about 5000 tonnes/year.
- NO_X reduced by about 5% or 600 tonnes/year.
- Methane emissions reduced almost completely, ie. 55 million m^3/year, which is equivalent in greenhouse effect to 1650 million m^3/year of CO_2, ie. a 420 MW thermal plant operating 100% of time.

There are a number of regulatory issues which need to be addressed as part of the project implementation process. These are discussed in Section 9 of this report.

9.0 MRA DUCT - LAND USE AND ENVIRONMENTAL CONTEXT

The intent of this section is to:

- i) indicate the environmental issues or impacts, both positive and negative, that may arise from the construction and operation of the project;
- ii) identify pertinent legislation, both federal and provincial, that may apply to the project; and
- iii) raise any other related matter that may impinge upon or facilitate the project's implementation.

9.1 IMPACTS

The project is to locate a conduit approximately 4.8 m (16 ft. in diameter) between Lingan and Phalen Collieries and the Lingan Generating Station. Several routings are being considered. The potential environmental and socio-economic impacts, positive and negative, that may be derived from the construction and operation of the project can be summarized as follows:

9.1.1 Benefits or Positive Impacts

- i) upon completion of the conduit the emission of methane to the atmosphere will be reduced;
- ii) upon completion of the conduit the emission of sulphur and nitrogen oxides to the atmosphere will be reduced;
- iii) during construction there may be additional employment opportunities created for the local labour force; and
- iv) the implementation of the project will enhance the financial efficiency of the associated plants.

9.1.2 Costs or Negative Impacts

i) the removal of vegetation and soil to clear the conduit route, including the upgrading of any rights of way if applicable, may alter drainage flows, may create additional run off and may cause erosion;

ii) the removal of vegetation and soil as described in i) above may disrupt and degrade habitat and may create an unsightly appearance;

iii) the onsite construction of the pipeline may result in increased dust and noise levels;

iv) the transportation of debris and construction materials to and from the site will necessitate increased levels of truck traffic;

v) the construction (and operation) of the conduit may disrupt the numbers and types of animal/bird species that presently inhabit the area;

vi) any construction debris remaining after site clean-up would be a degradation of the surrounding environment;

vii) there may be actual or perceived safety risks regarding potential leaks or the combustibility of the gas in the conduit;

viii) local residents may have concerns and negative perceptions about conduit operation, safety and health derived matters; and

ix) the visual impact of a 4.8 m (16 ft.) conduit on the landscape may be less appealing than what presently exists.

9.2 RELEVANT LEGISLATION

Comprehensive environmental legislation is a recent development at both the federal and provincial levels of enactment; it is a complex area of law and one that is evolving rapidly. In general terms there are at both legislative levels:

i) omnibus acts which aim to establish procedures to ensure the identification of all environment impacts or to establish principles or standards of general application; and

ii) acts of specific application which provide standards, procedures, etc., for a specific purpose or operation.

The Canadian Environmental Protection Act would be an example of the former; the Dangerous Goods and Hazardous Wastes Management Act an example of the latter. The paragraphs which follow identify the key enactments that have relevance to the project.

9.2.1 Federal Legislative Context

Although the project is located totally on provincial lands, reference must be made to the federal environmental assessment process and to the Canadian Environmental Protection Act. Other federal legislation may provide direction to parallel provincial legislation and will be identified as necessary.

9.2.1.1 Environmental Assessment Review Process (EARP)

The federal environmental assessment review process was instigated in 1973. A response to increasing public concern for the environment. In 1984 an Order in Council established the EARP Guidelines Order which has been determined by the courts to be a law of general application. Clause 6 of that Order reads as follows:-

These Guidelines shall apply to any proposal:

a) that is to be undertaken directly by an initiating department;
b) that may have an environmental effect on an area of federal responsibility;
c) for which the Government of Canada makes a financial commitment; or
d) that is located on lands, including the offshore, that are administered by the Government of Canada.

Each of the four subsections of Clause 6 stands on its own and, as long as a federal decision is required, each is a sufficient trigger of EARP. The federal assessment process may in certain circumstances involve three steps:

i) screening, a process to determine the potential environmental and directly related social effects of a proposal and the significance of those effects;

ii) initial environmental evaluation, a process to investigate in greater detail uncertainties identified by the screening; and

iii) referral for public review and the undertaking of a full environmental impact assessment.

The initiating department is responsible for i) and ii) above; an initial environmental evaluation will only be necessary if unresolved questions remain on completion of the screening. Similarly the project would be referred for public review only if there were substantive unresolved environmental problems remaining after completion of the initial environmental evaluation and/or serious public concern had been voiced.

The fact that a province may have primary responsibility in a specific set of circumstances, as it does in this instance, does not mean that a federal department or agent can defer to the province in respect to its decision making on environmental matters. Although the law does not necessarily require CBDC, a federal crown corporation, to adhere to the EARP process, it would increase their credibility in the eyes of the public to comply. Further in the context of this project compliance would be straight forward; it would require only that step i), the initial screening process, be appropriately documented in order to demonstrate (to a court if needed) that EARP has been respected and to have information about the proposal readily available if requested by the public.

9.2.1.2 Canadian Environmental Protection Act (CEPA)

The full title of this legislation, "An Act respecting the protection of the environment and of human life and health," clearly defines its purpose. The Act seeks to provide a comprehensive framework to assist governmental control of toxic substances throughout their life cycle - from their development through to their manufacture, transport, distribution, use, storage, and, finally, their disposal as waste.

In Part V the Act addresses the topic of international air pollution and provides the authority necessary to promulgate regulations in respect to such pollution. These regulations serve two functions:

1) to indicate to the international community that Canada has met its treaty obligations; and
2) to serve as guidelines or standards to be followed by the provinces.

In fact, all Provinces have adopted standards for air emission that exceed the federal requirements; adherence to such standards will therefore ensure compliance with CEPA.

9.2.1.3 Other Federal Statutes

Several other federal statutes bear upon pollution, landuse and other factors pertaining to the environment. These include the Fisheries Act, the Navigable Waters Protection Act, the Migratory Bird Act. The Canadian Wildlife Act and the Endangered Species Act. Given the location, intent, and nature of the project, however, these acts have little or no relevance to the project's implementation.

9.2.2 Provincial Legislative Context

The province not only exerts jurisdiction over the use of land within its boundaries, but ensures through legislative mechanisms that projects are developed and function in an environmentally appropriate manner. The key principles and requirements of pertinent enactments are outlined below; these enactments include:

Environmental Protection Act, R.S.N.S., 1989, c150.
Environmental Assessment Act, R.S.N.S., 1989, c149
Pipeline Act, R.S.N.S., 1989, c345
Dangerous Goods and Hazardous Wastes Management Act, R.S.N.S., 1989, c118
Private Ways Act, R.S.N.S., 1989, c358

In reviewing the legislative context, reference will be made to other acts that either have a bearing upon the development of land, or that may in some way relate to the operation of the project.

9.2.2.1 Environmental Protection Act

The purpose of the Act as stated in Section 2 is to provide for the preservation and protection of the environment. In this context, pollution is defined as

> "... a detrimental alteration or variation of the physical, chemical, biological or aesthetic properties of an environment which results or may result from an act or omission over which the Legislature has jurisdiction."

No construction or modification of a facility which may cause pollution shall commence unless plans and specifications are submitted and approved by the Minister [S. 23 (1)]. Further, if the Minister believes that a plant is discharging waste in excess of recommended standards, he may order that the emission be stopped or control equipment be installed. Of particular relevance, however, to the proposal is S. 30 (1) of the Act which states that:

> "A person responsible for an existing source of waste discharge or other pollution may submit to the Minister a program to prevent or to reduce and control the existing or additional emission or discharge into the environment of any waste from the source of the waste discharge or other pollution."

The project as defined is designed with the intent of reducing an existing emission to the atmosphere and of enhancing the current/proposed plant operations. In making its submission to the Minister as required by S. 23 (1) of this Act, the Proponent is advised to make reference to S. 30 (1).

9.2.2.2 Environmental Assessment Act

The purpose of this Act as stated in Section 2 is to:

(a) protect the environment and quality of life of the people of the Province;

(b) provide for the environmental assessment of undertakings to identify and correct or prevent, early in the planning process, potentially damaging environmental impact and thus avoid considerable costs for the adjustments or remedies which might otherwise be necessary after an undertaking has been completed;

(c) provide for public consultation respecting the potential environmental impact of an undertaking;

through the institution of environmental assessment procedures in respect to an undertaking that may be potentially damaging to the environment.

Unless specifically exempted by virtue of Section 4 (2) or (4), and this project is not so exempted, this Act applies. The Proponent shall, therefore, register the undertaking with the Minister whereupon the Minister shall determine in accordance with S. 7 whether:

(a) a preliminary report is necessary;
(b) an environmental assessment report is required; or
(c) an environmental assessment report is not required.

Should a preliminary report be necessary, the Minister shall provide the Proponent with guidelines for its preparation. In the unlikely event that a more detailed environmental assessment report would be required, more comprehensive guidelines and terms of reference would be prepared which would include plans for public consultation.

Given that the intent of the project is to reduce the emissions to the atmosphere in accordance with S. 30 (1) of the Environmental Protection Act and that the adverse impacts on the environment are either minimal or can be effectively mitigated, it is unlikely that an environmental assessment report would be required. A preliminary report as defined by this Act may be requested.

9.2.2.3 Pipeline Act

As defined in Section 3 (1) (k), a pipeline encompasses pipes and installations for the transmission of:

i) gas;
ii) oil;
iii) fluids from a well;
iv) water or effluent used or produced in connection with a well or the production or manufacture of gas or oil.

Unless exempted, no person shall construct a pipeline or any part thereof except pursuant to a permit. The exemptions as specified in Section 5 of the Act include:

> A pipeline situated wholly within property used for a refinery, absorption plant, processing plant, coal processing plant, marketing plant or manufacturing plant.

Over and above the need for a permit to conduct the pipeline in whole, or in part depending on the application of S. 5 above, a license will be required for its operation pursuant to S. 11 of the Act.

Of further relevance to the project is Section 27, which indicates that approval can be sought from either the Minister of Transportation and Communication or from the local authority, whichever is appropriate, to construct a pipeline on, across, over or under any highway or road.

9.2.2.4 Dangerous Goods and Hazardous Wastes Management Act

This Act applies to the handling of dangerous goods for any purpose and the handling of hazardous waste on property owned by the person responsible for it or elsewhere [S. 3 (1)]. Section 4 (1) requires that a person responsible for dangerous goods notify the Minister, as required by the regulations, regarding their location, approximate quantities, general purpose for which they are kept and precautions being taken for handling and storing them. Although methane identified as a hazardous material, there does not appear to be any specific permitting requirement. The proponent however would be advised to inform the Minister of the parameters of the project.

9.2.2.5 Private Ways Act

This Act provides a means for every owner or occupier of a mine and others to acquire easements to transport products of a mine over land they do not own by presenting a petition to the Governor in Council in the form prescribed. This is detailed in Section 2; the content of a Petition must include:

(a) the nature of business which such owner or occupier is desirous of carrying on;
(b) a description of the property over which it is sought to obtain a right of way;
(c) the width of such a right of way;
(d) the nature and extent of the right required; and
(e) the amount which such owner or occupier has offered to the owner or owners of the lands sought to be crossed for a right of way across the same.

This mechanism would have some relevance if the route selected crossed private lands and no easement was forthcoming from the registered land owner.

9.2.2.6 Other Provincial Legislation

Several other provincial enactments have a bearing on the use or protection of land or upon various environmental concerns within the Province; such enactments include, but are not limited to, the following:

Wildlife Act, R.S.N.S., 1989, c504
Special Places Protection Act, R.S.N.S., 1989, c438,
Ozone Layer Protection Act, R.S.N.S., 1989
Water Act, R.S.N.S., 1989, c500

Planning Act, R.S.N.S., 1989, c346

These enactments provide the substance to specific facets of environmental law. Given the nature of the project, however, its location on lands owned, or largely owned, by the Proponents and the current predominantly industrial use of abutting lands, these enactments have little, if any, direct relevance.

9.3 RELATED MATTERS

In large measure, the safe operation of the project in an appropriate location will be ensured by adherence to the requirements of the statutes identified. Only two additional matters indirectly related to location and operation can be raised, these are:

i) issues concerning rights of way; and
ii) issues of liability in respect to nuisance.

9.3.1 Rights of Way

To fully examine the topic of rights of way as it relates to the routing of this conduit, it would be necessary to have explicit information on land ownership and on traditional usage patterns. Nevertheless, it can be stated that subject to general statutory restrictions such as those, for example, that may be imposed by land use planning legislation, the fee simple land owner, free from incumbrances, has the exclusive right to do on it anything that does not so affect other land, or its occupiers, or to cause a nuisance or injury.

Easements may impinge upon how land is used; they can be created by statute, expressly by implication, by necessity, or by prescription. As indicated in Section 9.2.2.5 above, the Private Ways Act provides a means for mine owners to acquire easements that they may need to transport the produce of their operation over land they do not own. On the other hand, local land users might be able to create an easement of necessity if the proposed conduit were to block their access to lands. The topic is a complex one and must be carefully considered in the determination of a pipeline route.

9.3.2 Liability in Respect to Nuisance

In law there is both a civil liability for nuisance and a statutory responsibility. In respect to the latter, Section 51 (1) of the Health Act, R.S.N.S., 1989, c195 states:

> No person shall put or cause to be put in any place, on land or water, any offensive matter or thing likely to endanger the public health or likely to become or cause a nuisance.

In the context of civil liability, a person whose property is physically damaged or who suffers substantial interference with the use and enjoyment of property as an indirect result of environmentally damaging actions by another party, may bring an action in private nuisance against the party responsible.

The issue of liability must be addressed, but it does not inhibit the effective implementation of the project.

9.4 ACTIONS ARISING FROM ENVIRONMENTAL LEGISLATION

There are two distinct types of action necessary to respond effectively to the requirements of the environmental legislation; these are:

i) those actions necessary to meet assessment procedures; and

ii) the approvals/permits necessary to ensure compliance with specific enactments.

9.4.1 Assessment

The primary requirement is to meet the stipulations of the provincial legislation, namely:

> to register the project with the Minister of the Environment in accordance with the Environmental Assessment Act. If a preliminary report is deemed to be necessary, the Minister shall provide the Proponent with guidelines for its preparation. Public consultation would only be required in the unlikely event that an environmental assessment report is requested.

With respect to the federal assessment context, the Proponent is recommended to:

> document the initial screening process and to have available a succinct project description to demonstrate, if necessary, compliance with the federal assessment procedures.

9.4.2 Approvals/Permits

The following approvals and permits for the project must be sought:

> approval of project plans and specifications by the Minister of Environment as required by S. 23 (1) of the Provincial Environmental

Protection Act. It is recommended that in making the submission, reference to be made to S. 30 (1) of the same Act;

permits for the construction and operation of a pipeline by virtue of the Pipeline Act; and

approval to construct the pipeline on, across, over or under the highway/road.

9.5 CONCLUSIONS - MRA DUCT - LAND USE AND ENVIRONMENTAL ISSUES

The project will reduce the levels of methane, sulphur and nitrogen oxides emitted to the atmosphere; for this and other reasons the project should be implemented. Its implementation, nevertheless, will have to satisfy all pertinent legislative requirements. The preliminary appraisal of those requirements, presented in the preceding paragraphs, identifies no significant regulatory impediment.

Although no regulations specifically focus on the aesthetic or visual impact of the project, this issue may be raised by concerned citizens. Indeed a duct of this diameter (4.8 metres) will be very noticeable in the landscape if the proposed above ground design is pursued. To the extent possible, therefore, the routing should be kept at some distance from the public highway and in proximity to existing industrial uses. The alternative is to bury, or partially bury, the duct. This would inevitably increase costs by several million dollars and could only be considered after a detailed assessment of project viability. Such an assessment would require acceptance of the "notional" value of reducing SO_2 and other emissions in terms of real monetary benefits.

10. REFERENCES

1. Report "Utilization of Mine Return Air - Lingan Harbour Mine" for Cape Breton Development Corporation - May 1983,

2. Report "Methane Fuel - Power Generation Study" for Cape Breton Development Corporation - September 1988,

3. Letter 1990, 04, 25 - Cape Breton Development Corporation (John C. Campbell, P.Eng.) to Dr. David Granatstein, P.Eng., Chairmman - Technical Steering Committee - Mine Methane Utilization Project,

4. Letter 1990, 06, 26 - Nova Scotia Power Corporation (David L. Granatstein, Ph.D., P.Eng.) to Brian King, Fenco Shawinigan, Re: Mine Methane Project, Levelized Value for SO_2 Removal,

5. CANMET - MRA and Reburn Testing: Preliminary Summary presented by Dr. Fernando Preto at a Study Progress Meeting July 6, 1990,

6. Memorandum - Des Cousens - Special Studies Head, NSPC to Brian King, Fenco Shawinigan - Dated 1990, 07, 11 Re: NO_x Emissions Levels - Lingan Generating Station,

7. Telecon - NSPC - Richard Penny to Brian King, Fenco Shawinigan, July 1990. Power to drive the fan on NSPC Lingan Generating Station Site will be costed at 5.3¢/kWh. This is the value attributed to other Lingan "Stamtion Transformer" loads.

8. Chen, et al., Optimization of Reburning for Advanced NO_X Control on Coal_fired Boilers, JAPCA, 39(10), 1375 - 1379 (October, 1989).